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PREFACE.

The Author of the following Work deems it a sufficient apology for its appearance, that its arrangements differ widely from those of other treatises on the Use of the Globes. The experience of several years in this department of instruction having convinced him of the superiority of the plan here laid down, he has long found difficulty in adjusting the course of his teaching to the contents of that which he conceives to be the best of those treatises.

He is of opinion that the use of the Celestial Globe should accompany lessons on the Terrestrial Globe from the first: yet he is not acquainted with any publication in which the two globes are thus associated; and he is not aware that, in the whole routine of school occupations, there is any thing more at variance with perspicuousness than the very common use made of the line which, on the Terrestrial Globe, marks the daily change of the Sun's declination;—that line being frequently taken to represent the ecliptic, and the model of our Earth being turned in a contrary, or westward, direction, to show the risings, and bearings, and settings of the Sun. The Author thinks it must be owing to this inconsistency in the use of the Terrestrial Globe that, in numerous instances, pupils of superior intelligence, whose attention has been for some time engaged on it, (to the exclusion of a desired acquaintance with the appearances of the heavens,) are still possessed of very ambiguous notions respecting even the circumstances more immediately connected with the daily rotation of the Earth.

How far the great object of distinctness has been attained in the following treatise, the Author must leave to the decision of the unprejudiced instructor. It has been his earnest endeavour throughout, to enlist the *judgment* of the pupil in the attainment of what he conceives the principal objects of this department of study:—the correction of the misconceptions which early observant childhood will be found, in almost every instance, to have formed;—and the acquirement of the information generally sought for with eagerness at the time of life at which attention is given to the globes,—that interesting period when "attention is drawn from the discovery of what is new, to the examination of what is familiar, and the great work of comparison begins."

Something of the introductory nature of the Definitions and Illustrations, given in Class 1, (pp. 1—24), he has found indispensable, especially in the instruction of Young Ladies. The Definitions, &c., Class 2, are almost entirely new, and have been so arranged that they may be read as a kind of epitome.

The number of Problems and Exercises does not amount to sixty; but the converse of a problem is often embodied with it.

By a very early introduction of the Celestial Globe, the Terrestrial Globe has been kept to its purpose as an efficient representative of our planet: the circumstances of its surface being considered, first, in reference to Fixed Stars of very different declination; and, then, in reference to the varying declination of the Sun.

In the first two sections of Problems several new ones will be found; and the rules and arrangement of others differ considerably from what has hitherto been given. Several adaptations in the third section the Author may call almost entirely his own:—the subject of the *Trade Winds* has not, he believes, been yet introduced into this branch of instruction; and the results of *Precession* have been only very slightly touched upon before. He feels that, in dealing with such subjects, he has been treading on delicate ground; but he hopes that his illustrations and deductions may be considered to be fair, and equally instructive and important with those to which lessons on the globes have hitherto been confined.

With regard to the Appendix, the usefulness of the earlier rhymings has been tested. The few last pages must have the plea of good intention for their introduction. It is hoped that no critic eye will seek to discover in them a pretension to any degree of poetic merit. Appropriate extracts could not be gathered, in sufficient diversity, from our English Classics; and the concluding piece was designed only on this account, and to serve the purpose of familiar and connected illustration and reference.

It is the Author's practice, where time admits, to read, at the giving of each lesson, a few pages of the scientific notices. It is hoped, too, especially with the aid of the copious index, that these notices, as well as the familiar Illustrations of Class 1, may be found to interest the pupil in leisure hours.

LEWISHAM,
21*st March*, 1842.

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⁂ Attention is especially invited to the introductory illustrations; and the directions given in the pages accompanying the separate copy-lines of Part I. of these Lessons.

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LESSONS ON THE GLOBES.

DEFINITIONS, ILLUSTRATIONS, ETC.

CLASS I.

B A Point is that which has position, but not magnitude.

C A Straight Line is that which lies evenly between the two points at its extremities.

D A Plane is a surface, real or imaginary, such, that *any* two points in it being taken and joined by a straight line, the straight line will lie altogether in that surface or plane.

F A Circle is a plane figure, contained by one line which is called the circumference; and is such, that all straight lines drawn from a certain point within the figure to the circumference, are equal to one another.

G That point within the circle which is thus equally distant from the circumference, is called the Centre.

H A Circle may be described from any centre, at any distance from that centre.

Illustration. The sensible horizon, or circular boundary, which every individual, standing in a clear space, beholds around him, where the sky appears to touch the earth, has the station of that observer for its centre; and this horizon will vary its position with every step he takes.

The magnitude likewise, of this circular boundary, varies as his eye is elevated or depressed; for instance, if the individual ascend a ship's mast, or look out of its cabin window, or swim with his head just above the surface of the water.

K The distance of the centre from every part of the circumference is called the Radius.

The radius is also called a "Semi-diameter," because two radii in a straight line form a Diameter, or "measure through" the circle.

L The difference of direction of any two radii, or lines drawn from the centre of a circle, is called an angle. And this difference of direction is measured on the circumference, which, for this purpose is divided into 360 equal parts, called "degrees."

Degrees (°) are subdivided into sixtieths, called minutes (′).

Minutes (′) are subdivided into sixtieths, called seconds (″).

When the measurement of any angle is given, the angular point is considered as at the centre of a circle. Thus, we say, "an angle of so many degrees, minutes, and seconds," referring to any circumference drawn from it; as 25° 16′ 18″. Hence the magnitude of an angle does not consist in the length of the lines which include it, but in their difference of direction, or inclination to each other.

An angle is generally described by naming three letters, the middle one of which is standing where the lines meet, and the other two at their distant extremities.

M Every semi-circumference contains 180°, and every quadrant or quarter-circumference, 90°.

The angle of 90° is called a Right Angle, and the radii forming it are said to be Perpendicular to each other.

Angles are frequently referred to the right angle, and are termed Obtuse or Acute, as they contain a number of degrees greater or less than 90.

N The deficiency of any acute angle when referred to 90°, is called its Complement: thus, 60° is the complement of 30°; 41° is the complement of 49°; and 66° 32′, is the complement of 23° 28′.

P Every circumference measures exactly 44 seventh parts of its radius, or distance from the centre. Hence, the diameter or double radius is a little less than $\frac{1}{3}$ of the circumference; since the radius is a little less than $\frac{1}{6}$. Circumferences therefore are in proportion to their radii or diameters: so also are their 360th parts or degrees.

CIRCLE—CENTRE—CIRCUMFERENCE—DEGREE—ANGLE—PLANE—INSIGNIFICANT QUANTITIES—RELATIVE VASTNESS AND MINUTENESS.

[B] Let writing-paper of the smoothest surface and finest texture, be pierced with a finely polished needle:—if the paper be held *evenly*, and the needle be inserted *suddenly*, and *perpendicularly* to the *plane* of the paper, the hole so made will be *circular*, not else.

Of this circular hole we have to remark:—

1. That, like any other circle, the edge of the hole, or circumference, is, in all its parts, equally distant from a certain place or point within the hole, called its centre.

2. That this said point is level with the edge of the hole, and therefore *in the same plane* with it, and with the surface of the paper: that is, (supposing our needle to be of perfectly cylindrical form,) it is just *where* the needle-point *first touched* the paper before it really pierced it. This central point therefore, "has *position*, but not *magnitude*:"—it is now in vacant space.

3. That every individual spot or part of the circular edge, although at an equal distance from the centre, has a *different direction* with regard to the centre, from that of any other spot or part of the circular edge. And that this difference of direction, which any two of these points in the circumference have with regard to the central point, is called their angle or "bearing."

4. That, as there are considered to be 360 exactly equal parts in the whole circumference of any circle, and, as the size of a circumference and of each of its degrees is in exact proportion to its distance from the centre, so each of the 360 degrees of our needle-hole circumference will be in exact accordance with the thickness of the needle which formed it.

[C] Place the paper flatly on the table, and on another portion of the same table, let another sheet of paper of *the same thickness* be placed, also with perfect flatness. If the table be even, the *surfaces* of these two sheets of paper will be in the *same plane;* so also will our circular edge *and its centre* be, with the circumferences and centres of any needle-holes that may have been pierced in the other sheet of paper.

[D] The young reader will please to remark, that we have not said that these upper surfaces of the paper are in the same plane with the *table* surface; because they are raised above it by the thickness of the paper, which is not inconsiderable in this case.

[F] But, there is another table in a distant part of the room, corresponding in height, and the floor is level;—the surface of this also is in the same plane with our first table; and our thickness of the paper being *insignificant when compared with the distance between these tables,* we may now safely say, our paper surface also is *in the same plane.* So, also, are the surfaces of our sheets of paper and of our two tables, in the same plane with any other tables of the same height in the adjoining rooms on the same floor of the house.

If the eye be brought to the edge of the table, so as to look *along* its surface and the surface of our paper, at any objects placed at a moderate distance, (say at an opposite house or window,) that portion of the window or house seen to coincide with the surfaces of our table and paper, will likewise be in the same plane with them, and with the centres and circumferences of our needle-holes, and with *that part of space exactly intervening* in the width of the street, &c.

[G] Let the pupil endeavour to conceive of the centre of the needle-hole as the *position of our sun,* and of the circumference of the hole as representing the earth's annual path of 600 millions of miles around it; then, perhaps, the dotted pattern of the paper on the wall of the room, (if a considerably large one,) or points taken in the lofty ceiling, may represent the position of some of the nearest fixed stars, such as "Sirius," "Arcturus," &c., on the same scale of distance. It will be allowed, that no change of position in this tiny circumference of our needle-hole, can be considered as nearer to the wall, or more remote from it; than another.

We have said the *nearest* fixed stars: what then shall represent the most distant! Each improvement in the penetrating power of telescopes, has revealed new wonders in the infinity around us. Can the pupil's imagination furnish us with a room, the walls and ceiling of which shall be 35,000 times as distant as those of the present room are? Herschel has calculated such to be the relative remoteness of some of the wondrous objects he has viewed!

"But these estimates cannot be said so much to give us any notion of the power of the Deity, as to correct the errors we should fall into, by supposing His powers to have any limits like those which belong to our faculties: by supposing that numbers, and spaces, and forces, and combinations, which overwhelm us, are any obstacle to the arrangements which His plan requires. * * * The difficulty which appears to reside in numbers, and magnitudes, and stages of subordination, is a difficulty produced by judging from ourselves—by measuring with our own sounding line; when that reaches no bottom, the ocean appears unfathomable. Yet, in fact, *how* is a hundred millions of miles a *great* distance? how is a hundred millions of times a great ratio? not in itself * * * It is clear that the greatness of these expressions of measure, has reference to our faculties only. Our astonishment and embarrassment take for granted the limits of our own nature."*

---

^{H} To return to our needle-hole:—We have supposed its circumference to represent the orbitual path of our Earth around the Sun, placed at the centre. Uranus, the planet of comparatively late discovery by Dr. Herschel, the six moons of which have peculiarities of motion, "which seem to occur at the limits of our system, as if to prepare us for farther departure from all its analogies, in other systems which may yet be disclosed to us,"† has an orbit nineteen times as remote from the sun as our own. If our needle-hole then, were enlarged, until it could be measured by a shilling; we should have the orbit oft his remote wanderer on the same scale! The Comets, vanishing into space and re-appearing after lengthy periods, may, perhaps, extend their most eccentric courses to a distance double or treble of this.

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* Whewell's Bridgewater Treatise, pp. 276—7, which the young reader is strongly recommended to procure for perusal.

† Sr. J. F. W. Herschel, Cab. Cyclo. p. 299.

K We see, then, that the fixed stars "have no immediate relation to our system. The obvious supposition is, that they are of the nature and order of our sun * * * * If, then, these are suns, they may,* like our sun, have planets revolving around them; and these may, like our planet, be the seats of vegetable, and animal, and natural life: we may thus have in the universe, worlds, no one knows how many, no one can guess how varied; but however many, however varied, they are still but so many provinces in the same empire, subject to common rules, governed by a common power!†

"L But the stars which we see with the naked eye, are but a very small portion of those which the telescope unveils to us. * * * The number of stars which crowd some parts of the heavens, is truly marvellous; Dr. Herschel calculated that a portion of the milky way, about ten degrees long and two and a half broad, contained 258,000. In a sky so occupied, the moon would eclipse 2000 of such stars at once?‡

"If the first flash of that view of the universe which science reveals to us, does sometimes dazzle and bewilder men, a more attentive examination of the prospect, shows how unfounded is the despair of our being the objects of Divine Providence, how absurd the persuasion that we have discovered the universe to be too large for its Ruler."§

M We will tear off from the sheet of writing-paper, the part which contains the hole pierced by the needle, and wetting‖ it with water procured from a pond in which the vegetable matter has lately decayed, we will press it between two pieces of thin glass, and direct a high power of the achromatic* microscope to it. What do we see? A well! in which numerous animalcules, of different sizes, and of very different forms, are floating and diving! Each seems to be pursuing his own way, and enjoying, in the spacious area of our needle-hole, the unrestricted use of his powers of movement! How diversified the workings of those powers! Some appear crawling on the interior surface of the upper piece of glass; others, no sooner arrive at the surface of the water, than they quit it, again to make their way out of sight, through its depth—which, in this case is, of course, equal to the thickness of our paper! Whilst you are reading, a leech-like monster has attached himself by the tail to the circumference of our well; and, stretching, reaches nearly to the centre! What is that perturbation? a whirlpool!—it is caused by his wheels: he has two above his head; and their numerous exquisitely adjusted paddles, each of them much larger than many of the living individuals he is swallowing, are in eager and rapid revolution, and these are creating the vortex which is dragging towards him, in abundance, the prey which he would otherwise fail to reach. Now, having wrapped up and taken in his machinery, he has rolled himself into a ball, and all seems hushed; whilst from 60° distance from his station, there comes a globule! the bright specks I discover on him, show me that he is revolving as he steadily crosses the field of view! Has he 360° in his circlet too? How minute! Yet we may conceive each of those degrees to contain its 60 minutes, and each of those minutes to comprehend its 60 seconds! Is he rotating about his centre of gravity also! That it is impossible to tell: its position would depend upon the distribution of the several parts of his interior if he were mere matter; but he is organized and sentient; he acts with *purpose* to fulfil his *wants*, and his Creator and mine, the Upholder of the sun, and of the myriads of the rolling stars, has given him the nervous and muscular powers which are peculiarly fitted, at least to sustain, and to direct his course; for see! he has changed it.

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* See Index, "Double Stars."

† Whewell's Bridgewater Treatise, p. 270. ‡ pp. 270—271.

§ p. 288.

‖ The hole partly closes when the paper is soaked; it is better on this account to pierce a similar hole in a very thin piece of whalebone or ivory.

N Thus, whilst "the Telescope indicates the insignifi-

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[*] The application of the achromatic correction to the Microscope has admitted a ninefold quantity of light, and great distinctness. (See "*Microsc. Cab.*," by Mr. A. Pritchard, of Fleet Street, the coadjutor of Dr. Goring.) (See, also, H on p. 15.)

cance of the world I tread upon, the Microscope redeems it from all insignificance; for it tells me, that in the leaves of every forest, and in the flowers of every garden, and in the waters of every rivulet, there are worlds teeming with life, and numberless as are the glories of the firmament. The one has suggested, that beyond and above all that is visible to man, there may lie fields of creation, which sweep immeasurably along, and carry the impress of the Almighty's hand, to the remotest scenes of the universe: the other suggests, that within and beneath all that minuteness which the aided eye of man has been able to explore, there may lie a region of invisibles; and that, could we draw aside the mysterious curtain which shrouds it from our senses, we might then see a theatre of as many wonders as astronomy has unfolded, a universe within the compass of a point!"*

[B] A Globe or Sphere, is a body bounded by one uniform convex surface, every point on which surface is equally distant from a point within it, and which is therefore called its centre.

[C] If the globe or sphere rotate, the diameter about which it revolves, is called its Axis.

Every diameter of a sphere is called an axis; but that is emphatically the Axis about which the sphere revolves.

[D] Every section, or cutting, of a sphere, made by a plane, is a Circle.

A Great Circle is that which passes through the centre of a sphere, and divides it into two equal parts.

A Small Circle is that which does not pass through the centre of the sphere, and therefore divides it unequally.

[F] The Pole of a Circle of the Sphere, is a point on the surface equally distant from all points in the circumference of that circle.

Every Circle of the Globe, great or small, has two Poles; if the globe or sphere rotate, those are emphatically the Poles which are the extremities of the axis of rotation.

By an optical illusion, an individual in the open air, is impressed with the idea that every part of the expanse above him, is at an equal distance from him. If his finger be pointed to the horizon, and then carefully directed upward till it point vertically, (*i. e.* to his Zenith,

* Dr. Chalmers.

the *pole* of his horizon,) unless the individual be elevated he will then have described an exact quarter circle or quadrant of the heavens, and his finger and arm, when moved in this way, are said to have been moved in *Azimuth*.

G The Plane which would be described by splitting the the earth through the station of the observer from the North to the South Pole as far as to the axis, (and through the axis continuously to the opposite portion of the earth's surface,) is the "Plane of the Meridian." This plane may, as easily, be conceived to extend to the heavens, and to be carried, together with the residence of the observer, eastward, by the rotation of the earth on its axis.

When, by such rotation of the earth, this plane is brought to coincide with any heavenly body or bodies, they are said to *culminate*. When the sun culminates, it is noon, hence its name "meridian," (Latin, *meridies*.)

The boy who runs northward to raise his kite with a north wind, or southward, to raise it with a south one, sees his kite, and the string as it is being elevated by it, "cutting out" the plane of the meridian.

A meridian, strictly speaking, is the plane in which the whole edge of a large cutting instrument would move, both outside the globe and within it; if, from distant space it so advanced and fell upon the globe's surface, as to divide it into two equal parts, by entering it along the whole of a meridional semicircumference; thus cutting through the entire line of axis, and completing the division by passing out in like manner, through the whole of the opposite semicircumference, to persevere in its unwavering course beyond the globe into opposite space.

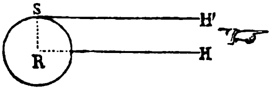
H Parallel Lines are such as, being in the same plane, will not meet however lengthened.

K Lines, and consequently the planes in which they lie, although they be not strictly parallel, may be considered as parallel, when the point to which they mutually tend is so distant as to render that tendency imperceptible, or insignificant.

L Lines and the planes in which they severally lie, although parallel and apart, may be esteemed as one line, or one plane, when considered as extending to an object so remote as to render their distance of separation insignificant.

Thus, the flat roofing of a house, and the several floors in that house, and the tables standing on those several floors, are all parallel and separate, but may be considered as together when referring their several planes to the station of an individual at the distance of four or five miles.

[B] Hence the Sensible Horizon, or circular limit of our view of the earth, seems to be in the same line, and therefore in the same plane, with the Rational Horizon, or circular limit of our view of the heavens; and may often, without error, be considered as coinciding with it.



Where S R the semi-diameter of the earth, or 4000 miles, is only the twenty-four thousandth part of the distance at which S H′ and R H, the planes of the sensible and rational horizon, meet, or where the sun is rising or setting.

[C] If a disk of wood, as the head of a barrel, when floating in perfect quietness on a calm sea, be supposed to increase all around, until it become the head of a barrel sufficiently capacious to contain the earth, (a globe in a cylinder,) the surface of that disk so enlarged, would describe "the plane of the horizon." It may further be conceived to extend around to the heavens.

[D] In strictness, only the man whom we have supposed (H on p. 1,) to be floating with his eye level with the surface of calm water, has his sensible horizon corresponding with his rational one; any elevation of the eye above the surface, enabling him to overlook a portion of the convex surface of the earth, and to see below the line in the heavens which is opposite to the earth's centre.[*]

This "Dip of the Horizon" is appreciable at a height less than that of a ship's deck, and is allowed for in estimating the altitudes of the heavenly bodies for nautical purposes.

[F] The Clouds and the tops of mountains, glisten with the splendour of the sun before his rising, and after his setting, to the inhabitants of the neighbouring shores.

Mr. Sadler, the aeronaut, who, on one occasion, ascended *after sunset* from our English coast, witnessed *a Western sunrise*, as he rapidly attained a considerable elevation.—Sir J. F. W. Herschel.

The uneven appearance of the Eastern edge of the Crescent Moon, is occasioned by the inequalities of her surface; her eminences, as she very slowly rotates on her axis, catching and reflecting the beams of the sun, hours before her valleys and cavities receive them: and when she is waning, the same appearance of her Western edge is occasioned by the light which is yet shining on her mountain tops, when their neighbouring valleys have lost it.[†]

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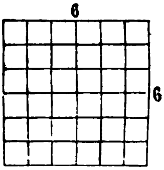
[*] But the water, the horizontal surface of which bounds the man's view, may be either level with the sea, or on a mountain-top; the height of the mountain being as nothing when compared with the semi-diameter of the earth, which we have seen is, itself insignificant.

[†] Those who are in the habit of using astronomical telescopes are often delighted with the beauty of this phenomenon, along the constantly varying boundary of light on the surface of our mountainous satellite. Even an inferior telescope, if on a stand, affords a very interesting view of it.

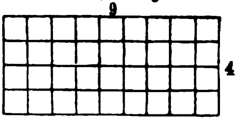
M A Parallelogram is a four-sided figure, having its opposite sides parallel.

The following are Parallelograms with their distinctions,

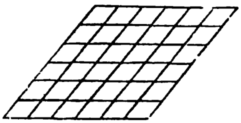
No. 1, Square.



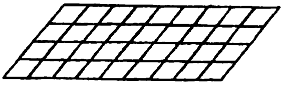
No. 2, Rectangle.



No. 3, Rhombus.



No. 4, Rhomboid.



A Trapezium is a four-sided figure, which has not its opposite sides parallel.

N The content of any right angled parallelogram, or "Rectangle," (such as figures Nos. 1 and 2,) is found by multiplying its length by its breadth.

P When the Rectangle has its length and breadth equal, it is a *Square*. Hence the product of any two numbers is called their *rectangle*; but the product, or rectangle, arising from the multiplication of a number by itself, is called its *square*.

If we conceive the figure No. 1, with its intersections, to be made of fine wire, and to sink into the thickness of the book, as into wax, until it arrive at a depth exactly equal to its width or length, each of its thirty-six meshes will cut out a little, solid, four-sided prism or pillar, capable of being again divided into six dice-like portions or cubes. Of these little cubes, so constituting the whole cube cut out by the sinking of the figure, there would thus be 6 × 6 × 6, or 216.

Q Hence the product arising from the multiplication of the square of any number by that number, is called its *Cube*.

R *Ratio* is the relation which two numbers, or the quantities which they represent, bear to each other. This relation is ascertained by dividing the one number by the other.

Proportion is the equality of ratios: hence, there must, at least, be three numbers or quantities to form a Proportion.

The width of the narrower figure No. 1, is 6; and has a ratio to 9, the width of the wider, but equal figure No. 2, of ⅔rds. But, since the areas of the two figures are equal, their lengths must bear to each other the same ratio, but invertedly, of their widths. Accordingly, 4, the length of the wider, has to 6, the length of the narrower figure, the same ratio, or ⅔rds. Hence, we have the proportion expressed thus 6 : 9 :: 4 : 6.

S A Triangle, or Trigon, is a figure inclosed by three straight lines.

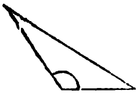
Triangles are distinguished as under:—

The *Scalene,* or unequal-sided triangle.

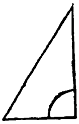
The *Isosceles,* or triangle of two equal sides.

The *Equilateral,* or triangle of three equal sides.

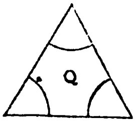
They are likewise named from their angles,



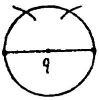
Obtuse Angled.



Right Angled.



Acute Angled.



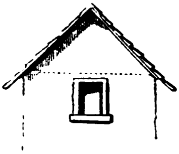
T All the three angles of any Triangle, amount exactly to two right angles or 180°.

This may easily be verified, in any particular instance, by describing arcs from the angular points as centres, (as in figure Q,) and setting off these arcs on a circumference drawn with the same opening of the compasses, as in fig. q.: they will be found, invariably, to measure off *half* of that circumference.

Hence, no triangle can have more than one of its angles a right angle; and, if one of them is a right angle, each of the remaining two is the Complement (N on page 2,) of the other.

V Any one of the sides of a triangle may be considered as the Base, according to the position in which we view it.

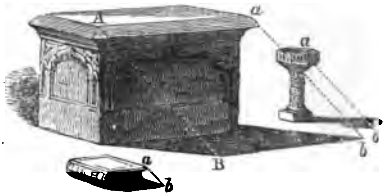
W If a triangle be Isosceles, or have two of its sides equal, the angles at its base will be equal.



That is, each equal side is supported by the other equal side, at an equal inclination. As the two sloping portions of the roofing of a house, which, if equal, will necessarily incline equally over the ceiling of the upper story.

Referring to T p. 12, if the angle made at the ridge uppermost part or ridge of the roof A be 90° or a right angle (M p. 2); then, since all the three angles equal twice 90°, and the other two angles are equal, each of the latter must contain 45°.

ˣ When the sun or moon is elevated 45°, the shadow of any object will be exactly equal to the perpendicular height of that object; and may be measured instead of it.



For, (as in the figure) the extremity of the object, A, is in the same plane, and also in the same straight line, with the sun and with the extremity of its shadow, B: and since the horizontal shadow, and this plane or the straight line A B, make an angle of 45°; and the upright object itself, forming the other side of a triangle, makes 90° with the ground or shadow, the angle at the top, A, must also be 45°; and thus the shadow and the height of the object correspond in length.

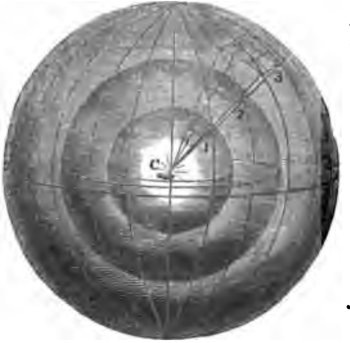
ᴮ A Luminary of equal brightness all around, such as the sun, or a star, or a ball of fire in the higher regions of the atmosphere, will send forth a *globe* of rays of light or heat.

ᶜ The influence of these rays will be intense in *the inverse ratio of the squares* of the distances of any objects upon which they fall from that luminary.

This will, perhaps, be more readily understood if we express it thus:—

The *diffusiveness* and consequent *weakness* of the influence of such rays of light or heat, must be considered by comparing the *squares of the distances* of any objects enlightened or warmed by them, from the source of such rays.

Illustration. Let us suppose a taper could be so placed as that its flame should occupy the exact centre of several concentric and transparent globes, (as C in fig. below). It may be perceived that the influence (as brightness or warmth) of the rays we have drawn, and, consequently, of all lying within them, will be *diffuse* and *weak* in proportion to the area or extent of surface over which they fall or spread.



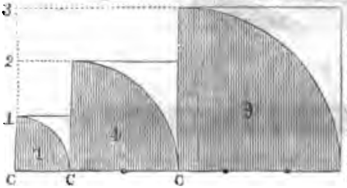
The globes drawn have their radii as the numbers 1, 2, and 3; but it will be understood that the portions of the surfaces enlightened, will be as the *squares* of these distances from the centre or flame; viz., that on the smallest globe the rays comprised within the lines we have drawn from the candle to the surface, occupy *one* space; but on the next a *fourfold* space, and on the outermost a *ninefold* space. Now 1, 4, and 9, are, respectively, the squares of the numbers or distances 1, 2, and 3. If we could place an attracting body, as a magnetic ball, at this centre, instead of the taper flame; or, if we suppose a sounding body to be stationed there, as a buzzing bee; the weakness of the attracting force, or the weakness of the sound (impediments being removed) would follow the same law. This is, in fact, the great law of gravity, and of any influence proceeding from a point.

[D] We may remember, from the foregoing illustration, that the *Surfaces of Spheres*, are in proportion to the *squares of their radii*, or of their diameters. Thus, our two feet wide globe has a surface four times that of a one foot wide globe, and our three feet wide globe, a ninefold surface: and the mapping of these globes will, of course, follow these ratios; for each of the several portions we have drawn as enlightened by the taper, is contained the same number of times in its respective globe-surface.

[F] The *Solid Contents of Globes* of equal densities must, however, be considered by comparing the *cubes of their diameters*, like the contents of all solid bodies that are "similar" to one another. Thus, a two feet globe has a solidity eight times; a three-feet globe twenty-seven times; and a four-feet globe sixty-four times that of a one-foot globe.

[G] Circles (circular spaces) must, in like manner, be compared by considering the squares of their radii, or of their diameters.

Illustration. The three following are Quadrants, (quarters of circular areas) described with the radii 1, 2, and 3, respectively, and included in squares constructed on those radii.

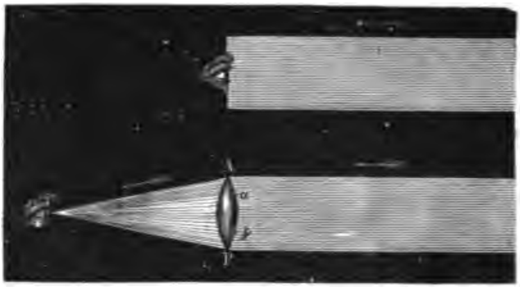


We think the Pupil will allow, without difficulty, that each of the larger quadrants, with its including square, is only a magnified representation of that which precedes it; and, therefore, bears to it the ratio which the square of its radius bears to the square of the radius of the other. Thus, the third quadrant bears to the first quadrant, the ratio which 9 (the square of 3, its radius,) bears to 1, the square of 1; and to the second quadrant, the ratio which 9 bears to 4, the square of 2. Hence, the circles of these quadrants are large in the same ratio.

[H] The quantity of light received from an object into each of two telescopes, will, therefore, be in the ratio of the squares of the diameters of the tubes, or of the glasses called the "object-glasses" at their ends; or, if the telescopes be of the reflecting construction, in the ratio of the squares of the diameters of the reflectors; and the internal arrangements being equally good, their powers of revealing the features of an object, will be in that ratio.

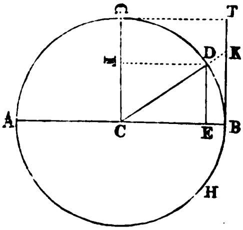
[B] The earth reflects the sun's rays upon the moon (as she upon the earth); so that, with the unassisted sight, we can frequently perceive the darker portion of her disk. Dr. Herschel's ten feet reflector, which has, perhaps, an aperture of fifteen inches diameter, collected sufficient of this earth-light, to show him even the most obscure of her spots on that portion.

[C] It was formerly usual to form deep well-holes in observatories, for the purpose of seeing the stars in the day time; because in the old uncorrected object-glass of telescopes, all the more oblique rays, that is, those admitted into the object-glass at a considerable distance from its centre, as those beyond *a* and *p*, (see fig. below,) were decomposed in passing through it, into their parts or colours, (see "*Refraction*,") and, causing distortion and confusion, were necessarily "stopped out."



The improvements introduced by Dollond and others,* in the construction of the object glasses of telescopes, now allow of their apertures being so enlarged, (see A P,) as to admit the light from a star in quantity sufficient (even when mixed with strong daylight,) to reveal the star to the eye in the focus of the instrument. A large star may be thus seen, even when near the sun; and Dr. Dick informs us, in his "Celestial Scenery," that he has frequently observed the planet Venus, even when at her superior conjunction; *i. e.*, just northward or southward of the sun, and at her greatest distance from us.

D The planet Jupiter, at its more than fivefold distance from the sun, receives, on any portion of its surface, less than one twenty-fifth of the light which a similar portion of our own planet's surface receives. (C on. p. 13.) If imagination can enable us to furnish its inhabitants with eyes, the pupils of which shall have a six-fold width, and consequently present a *thirty-six fold* surface for the reception of light, we may conceive of them as admitting to nerves, fitted to receive and enjoy it, a daily splendour far exceeding our own.



K Let the line A B be the diameter of a circle, and C the centre: then will the arc D B be the measure of the angle formed at C by the radii C D and C B.

If we now drop a perpendicular, D E, from D, the extremity of the measuring arc, upon C B, (the radius with which it was formed),

* Mr. Ross of Regent Street has very recently made material improvements.

such perpendicular will be the *Sine* of the angle measured by that arc.

In like manner, if we turn the figure, so as to make G C horizontal, and D F be let fall from the extremity D of the arc D G upon the radius G C, D F is the Sine of the angle measured by the arc D G.

Now, the Arc D G is the complement (N p. 2,) of the arc D B; for G B contains 90°.

For the same reason D B is the complement of D G.

The Sine of a complement, is, for shortness' sake, called its Cosine.

Hence, whilst D E is the sine of the angle measured by the arc D B, the line D F, or its equal E C, is its Cosine.

So, D E. or its equal F C, is the cosine of the angle expressed by the arc D G.

The arc A D, or what D B wants of being a semicircumference, is called its *supplement:* in like manner D B is the supplement of A D. Now D E is the sine of both of these arcs: that is, "Every sine is common to *two* arcs, which are supplements to each other, or make, together, 180°"

If a line, as B T, be drawn from B, the extremity of the radius, and at right angles to it, B T is called a *Tangent*. If the radius C D be lengthened so as to reach the tangent at K, C K is called the *Secant* of the arc D B, &c.

F The ancient Greeks employed Trigonometry (or "the measuring of triangles.") Hipparchus, one of their most celebrated astronomers, is supposed to have been the originator of the science. The Chord of the Arc (answering to the string of a bow,) was their means of solving problems. The Moors or Arabians, during the sojourn of astronomy with them,* and when Europe was in darkness, introduced the Sine or half-chord, an improvement of great utility. The Latin word *sinus* (a fold), is supposed to be a translation of an Arabic word referring to the two halves of the chord being conceived to be *folded* together. The Europeans have introduced the secant and tangent since the 15th century.

L Parallax is that apparent angular motion of an object which is occasioned by changing the point from which we view it.

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* See *Chronology* of Ancient Observations, (Index).

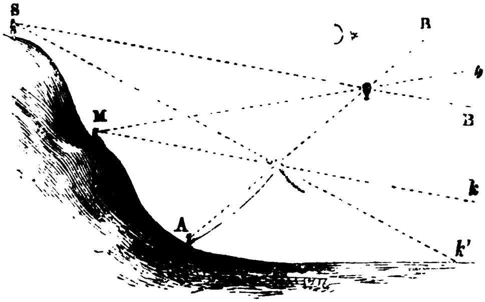


Illustration. Whilst the boy A at the bottom of the hill, at a certain instant, sees his kite and the distant balloon in the same line, and opposite the point B, (in the sky), M, who is half-way up the hill, sees the kite opposite k, and the balloon opposite b. But S, who is on the summit, sees the kite opposite the point k′, (on the ground,) and the balloon opposite B′.

M The amount of this parallactic displacement, is less as the distance of the object is greater. The difference of apparent positions of the distant balloon, is much less to A and S, than the difference of those of the kite. The moon having the same position, viz., close to the Evening Star from both stations, on account of the comparatively insignificant remoteness of those stations.

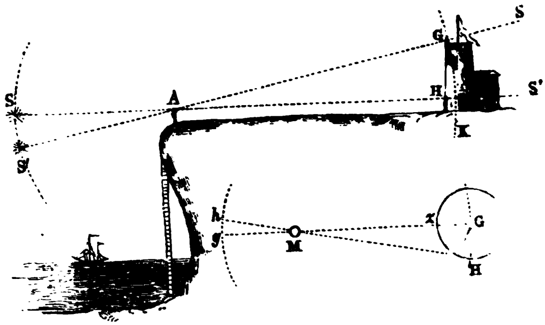
N Parallax, used astronomically, is the difference of apparent position of a heavenly body, viewed from the surface of the earth and from the earth's centre.

G An observer, who has the object in his zenith, sees it as if he were situated at the centre of the earth. Parallax, therefore, which is greatest when the object is in the horizon, is less as the altitude of that object is greater, and is nothing when it is vertical.

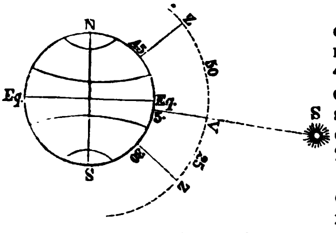
Illustration. Let A be an individual standing on the brow of a cliff, and G and H the stations of two inhabitants of a building. We will suppose it to be starlight, and G to record the star or point opposite to which the individual at A appears to be, from his station at the top of the tower, at the same instant that H records the star opposite to which A appears to be from his station at its base. It is evident that the arc, in the concave of the sky between such two stars, will have the same number of degrees as that which the building intercepts in the opposite direction from the view of A. (See note to L on p. 2.) If, with the distance A G, we draw an arc G K, then G H, the distance between the stations of the two inhabitants, will be the sine of that arc, *i. e.*, the sine of the angle of parallax.

In like manner, if G be the centre of the earth, M the moon, would appear from that station, (or from *Z*, the station of an observer who

has her in his zenith,) to be opposite to the point *g*; whilst to H, who has her in his horizon, she appears at *h*. Now the distance between G and H being known, (see Q p. 20,) the distance M G of the moon from the earth's centre, can readily be found from her parallax.



[P] The sine of any arc used to measure an angle has always a known ratio to the radius with which that arc was drawn. Thus, if the radius (as A G) be one mile or one inch, the sine of 14° will be a little more than a quarter of a mile, or quarter of an inch: sine of 30° will be exactly half a mile, or half an inch: sine of 49° will be a little more than three quarters of a mile, &c. The sine of the arc (h g,) or (H G,) the parallax of the moon, is found to be about $\frac{1}{60}$ of radius M G. Hence (H G) the semi-diameter of our earth, or 4000 miles, (which is in this case the sine,) is $\frac{1}{60}$ of the distance of the moon, (in this case our radius,) and 4000 × 60=240000 miles.



The sun is drawn as vertical in 5° of south latitude. The northern observer being in lat. 45°, would have it at a zenith-distance of 50°, whilst the southern observer, in lat. 30°, observes a zenith-distance of 25° only.

[H] Suppose each of two individuals situated on the same meridian, but one in north and the other in south latitude, to observe, on the same day, the zenith-distance of the sun's centre at his station, when it is at the highest, that is, on their meridian and at their common noon.

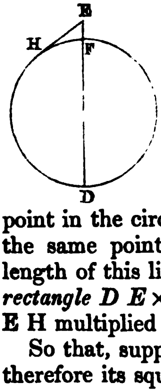
Then, as will be seen by the figure above, these two zenith-distances

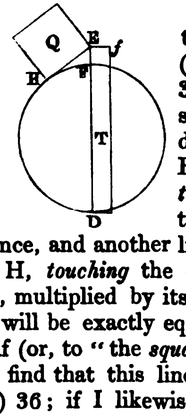
would, were it not for parallax, be exactly equal to their difference of latitude; and whatever discrepancy there might be found on comparing their observations, supposing them to be exactly made, and with proper allowance for the refraction of the atmosphere, *must be equal to this parallax*

"This once determined, the Horizontal Parallax," (and from it the distance of the sun,) "is easily found by dividing the angle of parallax so found by the sum of the sines of the two latitudes." (See Sir John Herschel's Ast. p. 191.)

The distance of the sun is such, as to cause his horizontal parallax, as found by this process and by others more elaborate, to be eight seconds of a degree: a quantity equal only to about one four-hundredth of that of the moon, and showing his distance to be about 400 times greater. (See M p. 18.)

Q But it remains to introduce the pupil to a method by which may be ascertained (although, from circumstances, not with great precision,) the diameter of the globe on which we live.

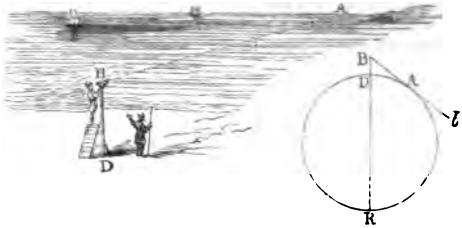




It is part of a theorem in Euclid, (Book III. Prop. 36,) that if a straight line be drawn from a point E outside a circle, *through* that circle to D, an opposite point in the circumference, and another line be drawn from the same point E to H, *touching* the circle; the whole length of this line D E, multiplied by its part E F, (or *the rectangle D E × E F,*) will be exactly equal to the length E H multiplied by itself (or, to "the *square of E H.*")

So that, supposing I find that this line E H is 6, and therefore its square (Q) 36; if I likewise know that E F is 2, E D must, of course, be 18; since it will take 18 to produce the rectangle T, (36) by multiplication by 2.

By referring to the illustration of the rectangle and the equal square, (page 12,) it will be understood that the length, D E, bears the same ratio to E H, the length of the square Q, that the width of that square bears to E f, the width of the narrow rectangle T.



[K] Suppose a pole 10 feet high to be placed on the sea-shore, and a telescope or theodolite, to be fixed horizontally to the top of it: it is found[*] that an individual looking through the telescope, (as fig. above,) can just discern the top of another pole of the same height, similarly placed on an opposite shore, at the distance of eight miles from him. That is, the top of the other pole, or some signal (as a brilliant lamp,) upon it, will be seen just peeping over the horizon at A.

Now it is plain that the line of sight B A, must just *touch* the earth in the horizon at A, *half-way* between the two poles; or at the distance of four miles from either of them. And the top of the upright pole B, is 10 feet above 'the circle of the earth,' and would, if it were to grow far enough downward, pass through the earth's *centre*, and become a *Diameter*.

Apply this experiment to the theorem on the page we have just attended to, and we shall see that 10 feet multiplied by the diameter of our earth, must, if the observation be correct, be equal to the square of 21,120 feet, or 4 miles, viz., 446,054,400 feet.[†] So that, dividing this square number by 10 feet, the width of our rectangle, (see p. 11,) we get 44,605,440 feet, or 8448 miles for our diameter; which, although not quite correct, is so only in consequence of the want of exactness in ascertaining the distance between the telescopes, and of the refraction[‡] of the atmosphere, which *throws out* the straightness of our line of sight; and, varying with the weather, enables the observer to look farther round the curvature of the earth's surface at one time than at another.

[L] An eye placed lower than B, or 10 feet, could not, of course, see this object. The horizon of a man six feet high, being distant not more than about three miles, and a boy of five feet seeing to a distance

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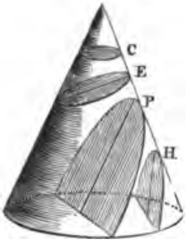
[*] Sir J. W. Herschel's Astronomy, p. 21.

[†] It may help the memory of the pupil, if we say that a field four miles square, would contain the same quantity of grass or corn, as a field of a length equal to the diameter of the earth, and ten feet wide only.

[‡] See Index "Light."

of not more than about two miles and a quarter. That is, the rate of curvature of our earth is in a similar proportion; viz., about ten feet in four miles; six feet in three miles; five feet in two and a quarter miles, &c.

ELLIPSE, PARABOLA, HYPERBOLA.

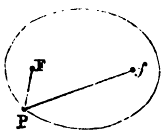


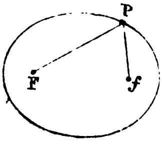
[R] These three figures, as well as the circle and triangle, may, all of them, be produced by the cutting of a Cone. They are therefore denominated "*Conic Sections,*" and may be briefly described thus:—

If the cutting plane be carried through *both sides* of the cone, *otherwise than parallel* to the base, (which is circular,) the figure will differ from a Circle, (C) and be elongated into an *Ellipse,* (as E).

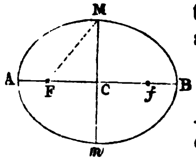
If the cutting plane pass through *one side* of the cone, *and through its base,* in a direction *parallel to the other side,* the figure will be a *Parabola,* (as P).

If the cutting plane pass *through a side and the base* in a direction *less inclined to the base than the other side is,* the figure will be an *Hyperbola,* (as H).





[S] If two pins be stuck in a smooth board, and the ends of a thread, considerably longer than their distance, be attached to them, the point of a pencil which keeps this thread stretched, if moved as limited by it, will mark out an Ellipse, which will be more or less like a circle, according to the degree by which the length of the thread exceeds the distance of the pins. The places of the pins will be the two focuses (*foci*). If we take the Ellipse and draw a line A B through the foci, and



take c, the middle point between them, and draw a line M m, crossing it at right angles to A B.

Then A B is the *Major Axis;* M *m* the *Minor Axis;* c is the *Centre*, and c F or c f, the *excentricity* of the Ellipse.

T The difference of distance of F from A and from B, will, of course, vary with the shape of the ellipse, *i. e.*, with its excentricity; but a line drawn from M to F, will always give the medium or *mean distance.*

Each of the "Conic Sections" has its peculiar properties, which are well known to mathematicians.

"They are naturally allied to each other, and one curve is changed into the other perpetually, when it is either increased or diminished. Thus, the curvature of a *circle*, being ever so little increased or diminished, passes into an *ellipse;* again, the centre of an ellipse going off infinitely, and the curvature being thereby diminished, it is changed into a *parabola;* and lastly, the curvature of a parabola being ever so little changed, there ariseth the first of the *hyperbolas*, the innumerable species of which will, all of them, arise orderly by a gradual diminution of the curvature; till this quite vanishing, the last hyperbole ends in a right line."—*Dr. Hutton's Mathematical Dictionary.*

V The Planets in their courses around the sun, describe Ellipses of very little excentricity, of which the sun is a focus.

"Three or four comets describe very long Ellipses, and nearly all the others that have been observed, are found to move in curves which cannot be distinguished from Parabolas. There is reason to think that two or three comets, which have been observed, move in Hyperbolas.

"Every thing that is said respecting the motion of a planet, or body of any kind, round the sun, in consequence of the sun's attraction, applies equally well to the motion of a satellite about a planet; since the planet attracts with a force following the same law, though smaller, as the attraction of the sun. Thus, the moon describes an Ellipse round the earth, the earth being the focus of the Ellipse: Jupiter's satellites describe each an Ellipse about Jupiter, and Jupiter is in one focus of each of these Ellipses: the same is true of the satellites of Saturn and Uranus."—*Professor Airy on Gravitation.*

METHODS OF MARKING THE FIXED STARS.

The most ancient method of distinguishing a star, is that which gives its place in the picture of its constellation; as "the first," (or westernmost,) "in the belt of Orion:" "the first in the left wing of Virgo," &c. The Arabians affixed names to the principal ones; and some of these names are still retained, as Aldebaran, Rigel, Fomalhaut, &c.

Bayer, a lawyer and astronomer of Germany, in the beginning of the 17th century, introduced the method of indicating the relative brilliancy or apparent magnitudes of the stars, in any constellation, in the order of the letters of the Greek alphabet. When the Greek letters are exhausted in this way, the stars next in brilliance are similarly marked by the small letters of the Roman alphabet, a, b, c, &c. Flamsteed, and the more modern astronomers, have agreed in using the letters of Bayer. There is also a numbering of the stars, which refers to their places in the several published catalogues of different astronomers.

It will be well for those who are unacquainted with the sounds of the Greek letters, to spell out their names as given below; as well as those words which are given in the next class of definitions. The capitals are seldom, if ever, used to the stars.

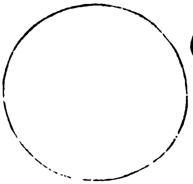
GREEK ALPHABET.

Α α	Ἄλφα	Alpha	a
Β β ϐ	Βῆτα	Beta	b
Γ γ ſ	Γάμμα	Gamma	g
Δ δ	Δέλτα	Delta	d
Ε ε	Ἐψιλον	Epsilon	e short.
Ζ ζ ζ	Ζῆτα	Zeta	z
Η η	Ἦτα	Eta	e long.
Θ ϑ θ	Θῆτα	Theta	th
Ι ι	Ἰῶτα	Iota	i
Κ κ	Κάππα	Kappa	k c
Λ λ	Λάμβδα	Lambda	l
Μ μ	Μῦ	Mu	m
Ν ν	Νῦ	Nu	n
Ξ ξ	Ξῖ	Xi	x
Ο ο	Ὀμικρὸν	Omicron	o little, or short.
Π π ϖ	Πῖ	Pi	p
Ρ ρ ϱ	Ῥῶ	Rho	r
Σ ς σ	Σῖγμα	Sigma	s
Τ τ ꞇ	Ταῦ	Tau	t
Υ υ	Ὑψιλὸν	Upsilon	u
Φ φ	Φῖ	Phi	ph
Χ χ	Χῖ	Chi	ch
Ψ ψ	Ψῖ	Psi	ps
Ω ω	Ὠμέγα	Omega	o great, or long.

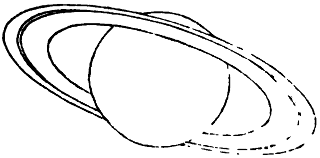
DEFINITIONS, ILLUSTRATIONS, ETC.

CLASS II.

1. **Planets** (πλανητης, a wanderer) are bodies belonging to our solar system; which, pursuing their courses to receive the light and heat of the sun, are seen reflecting his beams in constantly varying situations. The following are the chief, or primary planets, with their symbols and relative sizes.*

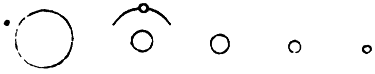


♃ Jupiter.
Diameter 91 thousand miles.



♄ Saturn.
Diameter 76 thousand miles.

♅ Uranus. ⊕ Earth. ♀ Venus. ♂ Mars. ☿ Mercury.



45 Thous. 8 Thous. 7¾ Thous. 4¼ Thous. 3 Thous.

Of these, Mercury, although brilliant, is seldom favourably seen on account of his proximity to the sun. Venus has the most splendid appearance, on account of her nearness to the sun and our earth; and Mars also is conspicuous, from his little remoteness from us. Jupiter and Saturn, although at great distances, are even more splendid than Mars, from the extent of their reflecting surfaces;

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* See also "Planetarium," in the Appendix.

whilst Uranus or Herschel, (called also the "Georgium Sidus," or "Georgian,") although of magnitude so considerable, at a distance double that of Saturn, is barely discernible by the naked eye.

2. **Minor Primary Planets** are those that have been detected between the orbits or courses of Mars and Jupiter; viz., Ceres ⚳, Pallas ⚴, Vesta ⚶, Juno ⚵. They are termed Asteroids; and being very minute, are never visible without the telescope.

3. **Secondary Planets, Moons, or Satellites,** (*Satelles,* Lat., an attendant,) are those which are seen to revolve about some of the primary planets, as auxiliaries to reflect the light of the sun upon the darkened portions of their surfaces.

Of these, besides that attending our earth, seventeen others have been discovered by the telescope; viz., four belonging to Jupiter, seven to Saturn, and six to Uranus.

4. **Fixed Stars** are distinguished from the planetary or moving bodies of our system, by the constant twinkling of their light. About 2000 only are visible to the naked eye; but it is calculated that, in the whole expanse of the heavens, there are a hundred millions within the reach of telescopic vision,—the whole number registered down to the seventh magnitude, amounting to between 15,000 and 20,000 (L on page 6).

5. **The Magnitude of a Star** is a term used to denote its apparent brilliancy. We see, without a glass, five or six gradations of star-light. Telescopic research has detected stars, which, from their small portion of brilliancy, might be classed as of the sixteenth magnitude; but the disks, even of those of the first magnitude, dwindle more nearly into *points,* in proportion as the construction of the telescope approaches perfection.

A scale of these gradations is given near the North Pole of every celestial globe. Thus, a star of the first magnitude is, in some editions, marked with eight petals or rays; a star of the second magnitude with seven petals, &c.

6. A **Constellation** is an imaginary arrangement of a number of fixed stars into the outline of a figure; as a bear, a dragon, a swan, &c. Constellations are referred to in the works of Homer and Hesiod, (900 years before the

Christian æra). They occur in the prophecy of Amos, near the same period; and Arcturus, Orion, and the Pleiades are mentioned twice, even in the book of Job).*

"The similarity of the constellations recognised in different countries, is very remarkable. The Chaldean, the Egyptian, and the Grecian skies, have a resemblance which cannot be overlooked. Some have conceived that this resemblance may be traced also in the Indian and Arabic constellations, at least in those of the Zodiac. * * * * * It is clear that fancy, and probably superstition, had a share in forming the collection of constellations. The stars were supposed to influence the character and destiny of man; and to be, in some way, connected with superior natures and powers.† We may, I conceive, look upon the formation of the constellations, and the notions thus connected with them, as a very early attempt to find a meaning in the relations of the stars, and as an utter failure."‡

7. Morning or Evening Star. Venus and Jupiter, as the most conspicuous of the planets, receive the names of Morning or Evening Stars, according as they are situated westward of the sun, and are therefore seen to rise before him; or are eastward of that luminary, and therefore appear in the evening after he has set in the west.

8. The Terrestrial Globe is a model of our earth, the third planet in order of distance from the sun; and is designed to exhibit the relative situations of its several countries and seas, and their varying positions in the light of any heavenly body, as our planet revolves on its axis and in its orbit.

Not more than one half of the surface of any globe can be enlightened, at any instant, by the direct beams of a distant luminary.

9. Axis of the Earth is the diameter about which it revolves with a uniform motion from west to east, (C on page 8).

10. Poles of the Earth are the points where its axis meets its surface, (F on page 8). The northern extremity of the earth's axis is called the *Arctic* Pole, because it is situated nearly beneath that part of the heavens occupied by the constellation of the Bear, (*αρκτος, arctos*). Hence also the southern or opposite Pole is called *Antarctic*.

For great Circles and small Circles, see D on page 8.

11. The Celestial Globe is a model of the apparent

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* See "Rhymes on the Constellations," Appendix.

† See "Astrology."

‡ Whewell's Hist. of the Inductive Sciences, pp. 134, 136.

sphere of stars, formed on the supposition of the observer's being situated at its centre, and viewing the stars on its concave surface.

12. POLES OF THE CELESTIAL SPHERE are those points which are exactly vertical to the two poles, or stationary points, of the earth's surface; and which, therefore, are not affected with that apparent westward motion which is common to all other points in the Celestial Sphere, as our earth's surface rotates eastward within it.

13. EQUATOR of the earth, or terrestrial globe, is a great circle passing, or supposed to pass, through all those parts of the surface which are equally distant from both poles; and which, being most distant from the axis, are carried the most rapidly eastward by the rotation of the globe.

14. EQUINOCTIAL of the celestial globe or heavens, is a line passing, or supposed to pass, over all those stars or points in the sphere which are equally distant from both Polar points; and to which, successively, the head of any Equatorial inhabitant is pointed as he is carried eastward by the earth's diurnal rotation.

When the earth is so situated in space, as that its inhabitants behold the sun coinciding with this line of stars, our nights are equal to our days; hence the name Equinoctial.

15. LATITUDE OF A PLACE is its distance northward or southward of the Equator, and is reckoned in degrees and parts of a degree.

For "Latitude of a Heavenly body," (see Index).

16. PARALLELS OF LATITUDE are small circles parallel to the Equator, which, on globes and in maps of the world, are generally drawn through every ten degrees.

17. DECLINATION OF A HEAVENLY BODY is its distance northward or southward of the Equinoctial, reckoned in degrees and parts of a degree.

Since the Equinoctial stars appear to pass vertically over the Equator, and the Polar points are vertical to the Poles, it is evident that the declination of any star, shows the latitude in which that star appears to pass vertically.

18. PARALLELS OF DECLINATION are small circles parallel to the Equinoctial, and corresponding to the parallels of latitude of the terrestrial globe.

19. PLANE OF THE MERIDIAN of any place, is an ima-

ginary plane, which, passing through the place and the whole axis of the earth, passes likewise through all situations northward and southward of that place, and through their several Antipodes, (Note to G on p. 9).

20. **Brazen Meridian** is the circle of brass within which the artificial globe is suspended by its poles.

On the terrestrial globe, the flattened and graduated surface of the Brazen Meridian represents a portion of the plane of a meridian extending beyond the earth's surface, and serves to find what places agree in meridian and time.

On the Celestial globe, this graduated surface of the brass meridian represents a portion of the plane of a meridian extended beyond the Heavens; and serves to show what heavenly bodies are situated in the same plane with our whole axis, and are therefore brought by the earth's rotation into the plane of a meridian at the same instant of time.

21. *Divisions of the Brazen Meridian.* The brazen meridian of either globe, is divided into semicircles, which have different uses. The upper semicircle has its quadrants graduated from the Equator or Equinoctial, northward and southward, and is used to point out latitude and declination. The under semicircle has its quadrants graduated from the Poles, to enable the student to elevate them above the wooden circle, as may be required.

22. **Meridians** (or, " Semi-meridians," or "Meridional Lines,") of the terrestrial globe, are semi-circumferences, passing through the poles, and showing what portions of the surface have a common meridian plane. They are sometimes drawn through every 15°, and sometimes, but less conveniently, through every 10° of the globe's circumference.

23. **Longitude of a Place** is the inclination of the plane of its meridian towards the east or towards the west, of a given standard meridian plane; and is reckoned in degrees and parts of a degree. For this purpose, the Equator of the terrestrial globe is divided into semicircles, one of which is graduated eastward and the other westward. The greatest longitude any place can have, is 180°, or half the circumference of the globe.

24. **The First Meridian** is that from which geogra-

phers reckon in assigning the longitudes of places. The ancient geographers measured their longitude from the meridian passing through Ferro, one of the Canary isles. The Dutch also reckon from the Peak of Teneriffe in that group; but foreigners generally, count longitude from the observatories of their respective nations; and the first meridian of English maps and globes, is that which passes through the Royal Observatory at Greenwich.

For "Longitude of a Heavenly body," see Index.

25. THE HOUR CIRCLE on the artificial globe, is a small circle of brass, attached to the extremity of the axis, and divided into parts corresponding to the twenty-four hours of the day, and their subdivisions; in order to adjust the proposed time to any proposed meridian.

There are various arrangements of the Hour Circle in various editions of the globes. Some have a double row of figures, others but one. Some have the hour circle placed under the brass meridian, which is used as its index: others have the hour circle attached to the brazen meridian on its outside, and stationary, whilst the time is shown by an index moving with the globe. The more simple and less expensive arrangement of an hour circle placed at each pole, *under* the brazen meridian, and with a double row of figures to that only which is attached to the terrestrial globe, is indispensable to the free use of the globes.

26. "HOUR CIRCLES," OR "HORARY CIRCLES," is a term also sometimes applied to those meridians which, on many terrestrial globes, are drawn through every 15° of longitude, and thus very conveniently divide the Equator on which it is reckoned, into twenty-fourths, or hours.

The Horizon (*ὁριζω*, *h*orizo, I limit,) is either Sensible or Rational.

27. The SENSIBLE HORIZON is that circular limit of a view of the earth's surface, (taken at sea, or on extended plains,) which is caused by the convexity of its figure.

A man of six feet stature, standing on the sea-shore, has his view limited by a circumference, distant only three miles. The greatest altitude, above the average surface, ever attained by man, was that of M. Guy-Lussac's balloon; viz., rather less than five miles; when his view comprehended $\frac{1}{1600}$ of the earth's surface, (F on p. 10).

28. THE RATIONAL OR TRUE HORIZON is an imaginary plane, parallel to the sensible horizon, and passing through the earth's centre to and beyond the heavens.

These two Horizontal Planes, (the Sensible and Rational,) although thus separated by 4000 miles, (the semi-diameter of the earth,) will appear to coincide when considered as extending to the stars, because the earth's diameter is but a point when compared with that extension, (B on p.10).

29. The **HORIZON OF THE CELESTIAL GLOBE** is the flat wooden ring, or portion of a circular plane which surrounds the globe and is concentric with it. It represents a portion of the plane of the rational horizon of any latitude to which the celestial globe is adjusted, and thus affords the means of determining the rising and setting of the heavenly bodies, their altitudes, bearings, &c.

30. **THE TERMINATOR** is the flat wooden ring surrounding the terrestrial globe, and concentric with it; and is designed to exhibit the position of the earth's surface, in the light of a heavenly body of any declination; but especially the seasonal distribution of sunlight arising from the position of the earth's axis with respect to the sun, on any day and hour for which the globe is adjusted.

31. *Markings of the Horizon or Terminator.* The different editions of the globes vary somewhat in their markings of this wooden circle.

It is divided into several concentric circles:—

The outermost contains the twelve months, printed underneath their days and the degrees of the signs of the Zodiac which correspond to those days.

Between the globe and these Signs, (which are given with their symbols and sometimes with their stars,) are the thirty-two Points of the Compass; and, still nearer the globe, are two circles of figures, of which the innermost always shows the Amplitude or degrees of distance from the east or west; and the other the Azimuth, or degrees of distance from the north or south. Several editions of the globes omit this Azimuth graduation.

32. **HEMISPHERE**, (*ἥμισυ* *h*emisu, half, and *σφαιρα*, a globe,) the half of a sphere when divided by a great circle or the plane which passes through its centre. Thus, the Celestial Sphere is divided into Hemispheres by the rational horizon: the Equator divides the earth into the northern and southern, and the plane of the first meridian divides it into the eastern and western Hemispheres.

33. **DIURNAL ARC** is the arc described by any heavenly

body from its rising to its setting; and is measured in time.

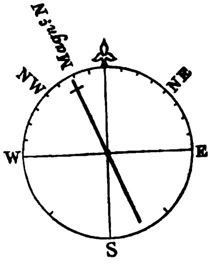
34. Nocturnal Arc of any heavenly body, is, in like manner, measured by the time of its absence from the celestial hemisphere of any latitude, or from its setting to its rising again.

35. Cardinal Points, (*cardo*, Lat. a hinge,) are those which are principal or reckoning points on the earth, or in the heavens; viz., the North, South, East, and West: the first degree of the signs Aries, Cancer, Libra, and Capricornus: the Zenith, Nadir, &c.

36. The Compass consists, *First*, of a circular card or paper, with the 360° of its circumference divided into thirty-two parts; each of these parts, therefore, containing $11\frac{1}{4}°$, and being called "Points of the Compass." *Secondly*, of a magnetised needle, which, being poized at the centre of the card, and constantly pointing towards the north-pole of our world, determines the position in which the card should be placed, in order that it may show the relative direction, or "bearing," of any part of the horizon.

The Mariner's Compass differs from the compass attached to Globes, or usually employed to adjust them, in having the card poized on its centre and moved by the magnet attached to its under surface.

37. Variation of the Compass. By the apparent positions and motions of the heavenly bodies, as caused by the rotation of the earth, it may be seen that the magnetised needle does not point *along* our meridian, or *duly* to the north; but, at present, $24\frac{1}{2}°$ westward of it (at Greenwich). The compass card therefore, must be moved about until its *Fleur de Lis* or north point be placed $24\frac{1}{2}°$ eastward of the pointing of the magnet, as a correction of this variation. (See *Magnetism*, Index.)



38. The Zenith is that point in the celestial sphere which is immediately overhead, and which is equally distant from all points of the horizon.

39. The Nadir is that point in the heavens which is diametrically opposite to our feet. It is the Zenith of our Antipodes.

Thus the Zenith and Nadir are the two poles of our horizon, and each is 90° distant from every part of it.

40. ZENITH DISTANCE of any celestial object, is the distance of its centre from the zenith, or the complement of its altitude above the horizon. (See illustr. H, p. 19).

41. POLAR DISTANCE of any celestial object, is an arc of the meridian contained between the centre of that object and the pole of the Equinoctial.

42. VERTICAL CIRCLES are imaginary circles of any bearing whatever, passing through the Zenith and Nadir of an observer, and therefore cutting his horizon at right angles. Thus the brazen meridian represents a vertical circle passing north and south.

43. PRIME VERTICAL is that vertical circle, which passing through the east and west points of the horizon, is at right angles with the meridian.

44. ALTITUDE of any heavenly body, is its distance above the horizon, reckoned in degrees on a vertical circle: hence it is the complement of the zenith distance.

45. AZIMUTH of any heavenly body, is the distance or bearing of its present vertical circle from the meridian, reckoned in degrees on the horizon.

Hence vertical circles are also called azimuth circles. Azimuth, therefore, means nothing more, than the distance at which any heavenly body would be found from the north or south of the horizon, if it were instantly to glide down, the shortest way, from its present elevation. The variation of the magnet from the meridian is ascertained at sea by comparing the true azimuth, found by calculation from the observed latitude and altitude, or by the Globe, with that shown by the Azimuth Compass.

46. AMPLITUDE is the number of degrees intercepted between the centre of an object when rising or setting, and the east or west point of the horizon.

The variation of the magnet may be found by contrasting the true amplitude, found by calculation, or by the globe, with that shown by the compass.

47. ANGLE OF POSITION, (or apparent bearing) of a given distant place, is the bearing of the zenith of that place from the meridian of the observer; and is reckoned on his horizon from that point (north or south,) over which the pole of the Equinoctial is elevated.

Hence it corresponds to the azimuth of that point of the heavens, which, at the time, is in the zenith of the distant place.

48. **Quadrant of Altitude** is the graduation of 90° of a large circle of the sphere, on a thin flexible strip of brass, provided with a pivot and screw. When attached by this means to the uppermost part of the brass meridian, it serves to trace out and to measure the arcs of vertical circles, the altitudes of stars, their azimuths, &c. There is an additional graduation of 18° in a contrary direction, for the purpose of measuring the depression of the sun, &c., which, thus serving to ascertain the duration of twilight, is called the "*Crepuscular*" graduation. (See *Twilight*, Index.)

Positions of the Sphere are three, **Right**, **Parallel**, and **Oblique**.

49. That position of the Sphere is called *Right*, which they have who live at the Equator; and who, having always a point of the equinoctial in the Zenith, have the Polar points in their horizon. To such inhabitants all the heavenly bodies rise and set, and have their daily courses at right angles with the horizon.

50. That position of the sphere is called *Parallel*, which would be presented to an inhabitant of either Pole; who, having the Polar point in his zenith, would have his horizon coinciding with the Equinoctial, and the heavenly bodies of one hemisphere only, constantly circling around him in lines parallel to it.

51. That position of the sphere is called *Oblique*, which they have who live neither at the Pole nor at the Equator; but who, having those stars culminating* vertically, which have declination answering to their latitude, have the Equinoctial stars culminating northward or southward at a corresponding zenith distance, and a portion of the heavenly bodies of both hemispheres rising and setting in courses oblique with regard to the horizon.

52. **Right Ascension** of any heavenly body, is that degree of the Equinoctial which comes to the meridian with it. It is called *Right* Ascension, because, at all places situated on the Equator, and having, consequently, a Right sphere, this degree not only culminates with the heavenly body, but also rises and sets with it. Right Ascension is reckoned from the first point of Aries eastward all round the globe, either in degrees and parts of a degree, or in hours, minutes, and seconds.

* G on page 9.

53. A SIDEREAL CLOCK is a clock so constructed, as that its hands may perform their revolutions, not in 24 hours, but in 23 hours, 56 minutes, 4 seconds, and nine hundredth-parts of a second;* and which, being set at the instant that the first degree of Aries comes to the meridian, will point out to the astronomer the right ascension which may be on the meridian, at any instant of its being consulted.

54. OBLIQUE ASCENSION of any heavenly body, is that degree of the Equinoctial which rises with it in an Oblique Sphere. It is reckoned, like right ascension, from the first point of Aries; and varies with the obliquity of the sphere, that is, with the latitude.

55. OBLIQUE DESCENSION of any heavenly body, is that degree of the Equinoctial which sets with it in an Oblique sphere; and, like the oblique ascension, is greater or less according to the latitude.

56. ASCENSIONAL DIFFERENCE is the number of degrees between that point of the Equinoctial which, in a given latitude, rises with a heavenly body, and its right ascension or the point which rises with it at the Equator and every where culminates with it.

Similarly, the corresponding number of degrees between the right ascension of a heavenly body, and that degree of the Equinoctial which sets when it is setting, is called its *Descensional Difference.*

57. DISC (διϲκος, a quoit,) is the circular face of the sun or moon, so called from its apparent flatness. The diameter of a disc is supposed to be divided into twelve equal parts, called "*Digits.*" Any portion of the circumference of a Disc is called its "*Limb.*"

58. AN ECLIPSE (εκλειψις, a falling away,) is "a privation of the light of one of the luminaries, by the interposition of some opaque body," either between that body and the eye, or between that body and the sun.

The term *Occultation* also, is applied to the interposition of the moon between us and a star or planet: *Transit*, to the passage of the inferior planets, Mercury and Venus, across the sun's disc. In both cases the commencement of the occurrence is called the *Immersion* of the star or planet, and the termination of it, its *Emersion.* The term transit is also constantly employed for the daily culmination of any heavenly body.

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* See definition *Sidereal Day*.

59. **Eclipse of the Sun** is the occultation or hiding of his disc, or of a portion of it, by the intervention of the moon.

Hence, at the time of a Solar Eclipse, the moon is vertical, or nearly so, where the sun is vertical.

60. **Eclipse of the Moon** is the obscuration of her disc by the shadow of the earth.

Hence, at the time of a Lunar eclipse, the sun is vertical, or nearly so, to the Antipodes of those who have the moon vertical.

61. **The Ecliptic**, in the heavens, or on the celestial globe, is a great circle drawn, or supposed to be drawn, over all those stars which are situated in the same plane with our earth and the sun, and over which that luminary therefore appears to pass as we revolve around him. The ecliptic derives its name from the circumstance of the moon's being situated in it at the time of eclipse. It is sometimes called the sun's path; but sometimes also, and more correctly, "the* heliocentric circle of the earth," as it marks out the real annual path of our planet, as it would be seen from the sun's centre. (See *Ecliptic Illustrations*, Index.)

The "Ecliptic" on the terrestrial globe, is nothing more than a record, given in a continuous line, of the degrees of latitude which, day by day, answer to the declination of the sun, as our earth revolves around him whilst keeping its axis invariably directed to the Polar point.

62. **The Obliquity of the Ecliptic** is the angle at which the ecliptic is inclined to the Equinoctial, and consists of 23° 28′. It is the angle at which the earth inclines its axis and, consequently, its Equator, whilst annually moving around the sun in the ecliptic plane. (See *Ecliptic Illustrations*, Index.)

63. **Equinoctial Points.** Those points of the celestial sphere, where the ecliptic is intersected by the Equinoctial, are called Equinoctial points. (See *Ecliptic Illustrations*, Index.)

64. **Solstitial points, or "Solstices,"** (Lat. *sol*, the sun, and *stare*, to stand,) are those points of the celestial sphere where the sun's apparent motion to the south or to the north ceases; and at which he, consequently, appears in that respect to *stand still*.

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* *ἥλιος* (*helios*) the Sun.

65. Tropics (τροπεω, I turn, because the sun turns back again when he reaches them,) are two imaginary circles, parallel to the Equinoctial, at 23° 28′ to the north and south of it, and passing through the solstitial points of the ecliptic. That in the northern hemisphere is called the Tropic of Cancer, and that in the southern hemisphere, the Tropic of Capricorn, because the sun at the respective solstices is situated in those signs.

The Tropics, when referred to the earth or terrestrial globe, are those two parallels of latitude which correspond to the greatest northern and southern declination of the sun, and to the inhabitants of which the solstitial points pass vertically. Hence the term "Tropical" is used to designate those portions of the earth's surface which are situated between these parallels, and exposed to the vertical rays of the sun.

66. Analemma, as applied to the terrestrial globe, is a calendar of the year, printed upon some vacant part of the surface of the globe from tropic to tropic; and so arranged as that each day may be marked upon the latitude answering to the sun's declination for that day.

67. Colures (κολουροι, mutilated,) are two great circles which are drawn through the Poles at right angles to each other, and pass through the Equinoctial and Solstitial points. They thus divide the ecliptic into four equal parts, and mark the four seasons of the year. They have their name because a portion of them is always hidden below the horizon.

68. Polar Circles (of the earth or terrestrial globe,) are two small circles, at such distance from the Poles or extremities of the earth's axis, as corresponds to the degree of inclination of that axis towards the ecliptic plane. Hence they are distant from the Poles 23° 28°, and are the parallels of latitude 66° 32′. The northern is called the *Arctic*, and the southern the *Antarctic* Circle. (See Definition 10.)

69. The Zodiac (ζωδιον, an animal,) is that circle of constellations through which the ecliptic plane passes, and which is so called because of its consisting chiefly of the imaginary figures of animals. It is "the area within which the apparent motions of the sun, moon, and all the greater planets are confined."

70. **Signs of the Zodiac** are the twelve Constellations through which the sun appears to pass during the year. The ecliptic is divided into twelve equal parts, corresponding to these signs, and each sign is subdivided into thirty degrees. The sun makes his apparent annual progress through the ecliptic, at the rate of nearly one degree in a day.

The names and symbols of the signs, and the days on which the sun enters them, are as follow.

NORTHERN SIGNS.

♈	Aries, the Ram	21st March.
♉	Taurus, the Bull	19th April.
♊	Gemini, the Twins	20th May.
♋	Cancer, the Crab	21st June.
♌	Leo, the Lion	22d July.
♍	Virgo, the Virgin	22d August.

SOUTHERN SIGNS.

♎	Libra, the Balance	23d September.
♏	Scorpio, the Scorpion	23d October.
♐	Sagittarius, the Archer	22d November.
♑	Capricornus, the Goat	21st December.
♒	Aquarius, the Water-bearer,	20th January.
♓	Pisces, the Fishes	19th February.

The first three northern signs, and the first three southern ones, are called *ascending* signs; because, when in them, the sun is increasing his declination. The other six signs, in which the sun is approaching the Equinoctial, are called *descending* signs.

⁂ Those of our young friends whose memories find difficulty in retaining dates, will probably derive much assistance from the memorial lines given in the Appendix. (See *Dates of the Zodiac*, Index.)

71. **Zones** (*ζωνη*, a belt or girdle,) are large divisions of the earth's surface, made by imaginary circles parallel to the Equator. There are five Zones, viz., the *Torrid* Zone, consisting of that portion of the earth's surface more directly presented to the heating influence of the sun: the two *Frigid* Zones, or regions surrounding the Poles, which,

from their situations are least exposed to that influence, and the two *Temperate Zones*, containing the latitudes which intervene between the Tropic and the Polar circle of each hemisphere.

The Torrid Zone extends from Tropic to Tropic, and thus has a breadth of twice twenty-three degrees, twenty-eight minutes, or 46° 56′. Each frigid zone consists of the segment bounded by a Polar circle; and consequently, includes all latitudes higher than 66° 32′, or within 23° 28′ of the Pole. Each temperate zone, being between the Tropic and the Polar circle, has 43° 4′ of breadth.

The ancient astronomers, being inhabitants of the north temperate zone, and finding that travelling farther northward led them into colder regions, as travelling southward did into warmer ones, were led to *assume* that the exact space between the tropics was uninhabitable from heat; and that also within the Polar circles, uninhabitable from cold.

72. Amphiscii, or Amphiscians, (αμφι, both, and σκια, a shadow,) the inhabitants of the Torrid Zone, because during one portion of the year, their shadows at noon are cast northward, and during the other portion, southward.

73. Ascii, (α, without, and σκια, a shadow,) the inhabitants of the Torrid Zone on the two days which they have the meridian sun vertical.

74. Heteroscii. (ἑτερος, different, and σκια, a shadow.) The inhabitants of the north and south Temperate Zones may thus be denominated with reference to the shadows of either; because the meridian sun, on any day, casts the shadow of the latter southward, whilst he casts those of the former northward.

75. Periscii (περι, around, and σκια, a shadow). The inhabitants of the Frigid Zones during their long period of sun-light; because the sun, during every twenty-four hours of that period, is in every point of the compass, and casting their shadows towards the opposite point.

76. Twilight. (Lat. *Crepusculum.*) See Index, *Light.*

77. Perioeci, (περι, round about, and οικεω, I dwell). Those who, whilst living in the same parallel of latitude, and having, therefore, the same seasons and lengths of days; have opposite hours of the same day, because they dwell in opposite longitudes.

78. Antoeci, (αντι, over against, and οικεω). Those who, whilst dwelling on the same meridian, and having, therefore, the same time of day; have similar latitude in opposite

hemispheres: hence their seasons are contrary, and the length of any day of the year in the one situation corresponds to the length of the night in the other.

79. ANTIPODES, (αντι, opposite, and ποδες, feet,) are those who are so situated on our globe, as to have their feet diametrically opposed. They have opposite longitudes, and equal latitudes in opposite hemispheres; consequently, their hours, seasons, and lengths of day and night, are not only different, but all exactly contrary.

80. CLIMATE, (κλιμα, an inclination or declining.) In the general acceptation of the word, is taken to signify the atmospheric temperature of any district; but, originally, it was applied to denote "that inclination of the axis of the terrestrial sphere, from which result the inequalities of day in different latitudes."

The ancients, deeming only a very limited portion of the earth to be habitable, reckoned seven such climates. There are now reckoned sixty of them; viz., thirty of each hemisphere, as follows:—

I. Twenty-four climates are reckoned northward, and twenty-four southward, from the equator, or where the day is invariably twelve hours, to the polar circle, where the longest day of each hemisphere contains twenty-four hours: the latitudes in which the longest day consist of exact half-hours, as 12½ hours, 13 hours, 13½ hours, &c., being the boundary latitudes of climates.

II. Six climates are reckoned in the Frigid Zone of each hemisphere, by months of continuous sun-light: the latitudes in which that period consists exactly of two, three, four, and five months, being the boundary latitudes of climates.

For "Atmospherical temperature," see *Heat* in the Index.

81. For SIDEREAL YEAR and SOLAR YEAR, see "*Precession of the Equinoxes*," Index.

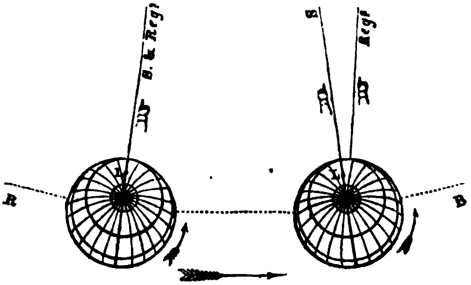
82. ASTRONOMICAL AND CIVIL RECKONING. Astronomers do not distinguish night and day, but begin from noon to count twenty-four hours. Thus one o'clock and eleven o'clock in the morning of the 1st Jan. 1840, are, respectively, 13 hours and 23 hours of 31st December 1839; and six A.M. of September 17th, will be 18 hours of September 16th: the hours from noon until midnight, alone corresponding with Civil or common time.

83. **Sidereal Day**, is the time occupied by one complete revolution of the earth about its axis, and consists of 23h. 56m. 4s. and nine hundredths of a second.

The Sidereal day is ascertained by observing the interval between two consecutive passages of a fixed star over the fine wires which intersect in the focus of a transit instrument, a telescope, the centres of the glasses of which are adjusted with the greatest exactness to the plane of the meridian; and which, in observatories of importance, is made to rest on massive stone piers, to insure its freedom from vibration, or other accidental disturbances.

84. **Solar Day**, is the portion of time intervening between two consecutive noons or midnights; and is of the *average* length of 24 hours.

It consists of the Sidereal day, or time of the complete rotation of a meridian plane, and that additional portion of time which it occupies in arriving, to coincide again with the meridian plane of the sun; which, during the sidereal day, is shifted nearly one degree eastward by the earth's progress in her path around that luminary.



Thus, let R B represent a portion of the earth's annual orbit; (the sun being near our book on the table, and the star *Regulus*, of the constellation Leo, on the distant wall): then the left hand figure represents the meridian of London coinciding with the sun and the star on 20th August; and the right-hand figure, the same meridian again coinciding with the sun on the 21st August to complete the solar day, about four minutes after it has completed the sidereal day by coinciding again with Regulus; the relative positions of the meridian, the sun, and Regulus, having been thus affected by the earth's orbitual motion.

85. **Apparent noon** is the exact completion of the solar day, or the instant at which the sun's centre coincides with

the meridian. The interval between one apparent noon and another, or the Solar day, is subject to continual variation; first, because the rate of motion of the earth in its orbit is unequal, and causes a corresponding inequality in the apparent ecliptic motion of the sun; and, secondly, because of the obliquity of the ecliptic path with regard to the earth's axis and equator.

86. True or Mean Noon is twelve o'clock, or the exact completion of twenty-four hours, as shown by a correct time-keeper, the going of which is exactly adjusted to the *average* solar day. Hence, the time as shown by such a clock, is called *mean* time.

87. Equation of time is the difference, on any given day, between apparent time, as shown by the sun-dial, and mean time, as given by a correct clock.

That portion of this discrepancy which arises from the obliquity of the ecliptic, is all that can be found by the globe; and, if this portion were the whole, the sun-dial and clock would agree on the equinoctial and solstitial days. But, in consequence of the united operation of the two causes, (see Def. 85,) the days on which the sun and clock agree, are the 15th April, the 16th June, the 1st September, and the 24th December; the clock being before the sun by fourteen minutes and a half about the 12th February: and after the sun as much as sixteen minutes and a quarter, about the 1st of November.

88. Lunar Day, is employed by some authors to designate the period elapsing between two consecutive times of any semi-meridian's coinciding with the moon; and is of the average length of 24 hours, 50 minutes, 48 seconds.

It consists of the sidereal day, or rotation of our meridian, and that additional portion of time which we occupy in passing, by the earth's rotation, from the plane in which we last left the moon, to coincide with the plane into which she has shifted, by performing a part of her monthly eastward revolution around us.

89. Aspect of a planet or star, is its apparent situation with regard to another planet or star.

Aspects are marked as under :—

☌ Conjunction, or in the same sign and degree of Longitude.
☍ Opposition, or in the exactly opposite sign and degree.
△ Trine, or one third of the ecliptic, or four signs apart.
□ Quartile, or one quarter of the ecliptic, or three signs apart.
⚹ Sextile, or one sixth of the ecliptic, or two signs apart.

N.B.—The Conjunction or Opposition of the moon, *i. e.*, her being new or full, is called her *Syzygy;* and her Quartile Aspect, as when she is "half-moon," her *Quadrature.*

90. Direct, a planet's motion in the Zodiac is said to be direct when, as we view it night by night, it is going eastward like the moon; or according to the order of the signs.

91. Retrograde. A planet's motion in the Zodiac is said to be retrograde when it appears to go contrary to the order of the signs.

92. Stationary. A planet is said to be stationary, when, in consequence of the earth's position and motion, as combined with its own, it appears for some time in the same point of the heavens.

93. Nodes. Are the two points at which the orbit, or path, of one planet, intersects the orbit of another planet. With reference to the plane of our orbit or ecliptic, that point at which the planet crosses to come northward, is called its *ascending* node, and is marked thus ☊; and the point at which it is going southward, or its *descending* node, thus ☋.

An imaginary line joining these points, and thus being in the plane of both orbits and passing through the centre of the sun, is called the *Line of the Nodes*.

94. Apogee, (απο, from, and γη, the earth.) That point in the elliptical orbit of the moon, which is most distant from the earth.

95. Perigee, (περι, near, and γη, the earth.) That point in the orbit of the moon at which she makes her nearest approach to the earth.

96. Perihelion, (περι, and ηλιος, the sun.) The nearest approach of a planet to the sun.

97. Aphelion, (απω, and ηλιος, the sun.) That point in the elliptical orbit of a planet which is most distant from the sun.

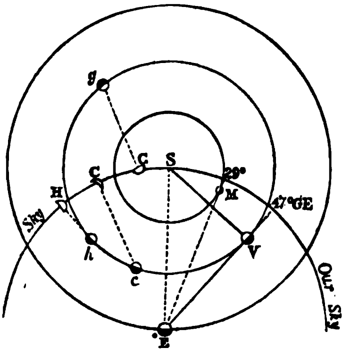
Perijove and *Apojove*, *Perisaturnium* and *Apcsaturnium*, are employed with reference to the satellites of Jupiter and Saturn.

98. Apsis, (plural Apses or Apsides,) are the points of greatest and least distance of a planet from its primary, or the body around which it revolves. Thus the Perihelion or the Perigee is called *the lower Apsis*, and the Aphelion or the Apogee, *the higher Apsis*; and an imaginary line joining these extreme points, is called "*the line of the Apses, or Apsides.*"

99. **Geocentric** place of a planet, is the position in which it would appear if viewed from the centre of the earth.

100. **Heliocentric** place of a planet, is the position in which it would appear if viewed from the sun's centre.

101. **Elongation** is a term employed to denote the apparent distance, in degrees of the sky, between an inferior planet and the sun. Our separation from Mercury is such as to cause his distance from the sun of 36 millions of miles, to appear to be 29 degrees of our sky, when his position renders that distance most visible to us. The greatest elongation of Venus is 47 degrees.



Let S be the sun and E the earth; then M and V may represent Mercury and Venus at their greatest elongations of 29° and 47°. By referring to P on p. 19, the pupil will understand, that taking the orbits to be as drawn, circular,* the triangle S V E is right-angled at V; and S V (the distance of Venus from the sun,) must bear the same relation to S E, (the distance of the sun from our earth, which is known to be 95 millions of miles,) that the *sine* of 47° bears to *radius*. The distance S V is, accordingly, 68 millions; and S M (that of Mercury) from the same considerations, 36 millions of miles.

The Phases (H, C, and G,) of Venus in our sky, as she varies her positions, h, c, and g, in her orbit, may perhaps be understood from the diagram. She is most brilliant when she appears, through the telescope, of the crescent form, (C) because of her being nearer to us, as (c); and consequently giving light from a portion of a disc of much greater diameter.

102. **Phase,** (*φασις*, an appearance,) is a term applied to the changes of appearance of the discs of the moon and other planets.

As not more than half of the surface of any planet can be enlightened at once by the sun-beams, it is evident, that our position with regard to that half-surface must determine the extent of it which is visible to us.

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* They are nearly circular.

Remark.—The moon revolves eastward, completely round the earth, in a portion of time during which the sun changes his apparent place comparatively little; and hence, at one time, presents towards us the whole of the light she reflects from him; at another time, no portion of it. The same phases result from the varying positions of the discs of the two inferior planets, when viewed in those positions by the telescope.

Mercury and Venus, performing their orbits around the sun within the compass of our own circuit, like the moon are alternately presenting towards us the whole of their enlightened sides, and various portions of those parts of their surfaces from which the sun-beams are absent.* With respect to the first superior planet, Mars, we must remember, that as he performs his circuit at a distance *beyond* us, half as great as our own whole distance from the sun, (and thus beholds our orbit at nearly 500 millions of miles from him); our greatest elongation, or utmost remove from the sun in his sky, is only about 48 degrees; and our earth must, necessarily, rise and set to him like Venus to ourselves: in other words, that we can never spend much time in his night-sky: accordingly, we find that a large proportion of his enlightened disc, or day hemisphere, is viewed through our telescopes. He is sometimes round, and sometimes gibbous like our moon when within two days of being full; but never horned, or even halved, like that satellite, or like Venus or Mercury.

The pupil is now prepared to answer a difficulty which may have arisen in his mind; viz., Why the discs of Jupiter and Saturn, and of their satellites, are *always* complete? At the vast distance of Jupiter, the apparent size of the earth's orbit is so minute, that our greatest elongation from the sun is inconsiderable, and our planet almost invisible in the sun's rays; and thus, as that portion of Jupiter which is turned towards us is likewise turned toward the sun, we constantly see him and his satellites without these changes or phases.

The same remarks apply, *a fortiori*, to the more distant planets, Saturn and Uranus.

For COSMICAL, ACHRONYCAL, and HELIACAL rising and setting, see *Precession of the Equinoxes*, Index.

103. ABERRATION. A very slight apparent displace-

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* See the foregoing wood-cut.

ment of the fixed stars, amounting only to about $\frac{1}{90}$ of a degree, occasioned by a want of correspondence in the direction of the orbitual motion of the earth, and of the motion of the light proceeding from them to the observer. (See *Light*, Index.)

Days and Hours of different Nations.

" The recurrence of light and darkness, of comparative warmth and cold, of noise and silence, of the activity and repose of animals; the rising, mounting, descending, and setting of the sun; the varying colours of the clouds, generally, notwithstanding their variety, marked by a daily progression of appearances * * * Man calls each portion of time in which this series of appearances and occurrences come round, a day: and such a group of particulars are considered as appearing or happening *in* the same day." —*Whewell's Inductive Sciences*, Vol. I, p. 112.

104. THE CIVIL DAY. The natural day is called the civil day with reference to the mode of its division by different nations for civil purposes. The ancient Hebrews computed their Civil Day, as the modern Jews do, from evening to evening: the compound word "*evening-morning*," is employed by the prophet Daniel to denote that period. This mode of computing the day, as well as that of the beginning of the year and of the week, originated in the command of God by Moses, as one means of distinguishing them from the neighbouring idolatrous nations. It is probable that, like the ancient Babylonians, Syrians, and Persians, whose chief idol was the sun, they, previously to their departure from Egypt, began their day at sun-rising.

The ancient Athenians began their civil day, like the Jews, at sunset. This is the practice also of the Chinese, and of modern Italy, where the twenty-four hours are reckoned in succession.* The modern nations of Europe, with this remarkable exception, follow our own method of counting the twenty-four hours in two equal portions of twelve hours, from midnight to midnight.

" The natural day commenced with darkness. The darkness and the light which succeeded the first chaos, are declared to have constituted the first day. In the same manner are reckoned the five succeeding days of the creation * * * The Sabbath, at its original institution, was a natural day, and when the Sabbath was renewedly enjoined upon the Israelites, it was required to be kept as a natural day. 'From even unto even shall ye celebrate your Sabbath.'" Lev. xxiii. 32.—*President Dwight on the Sabbath.*

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* The rising generation of Italy are now taught the *French* time.

The same author cites Homer, Hesiod, Lucian, Tibullus, and several others, in proof that a seventh day was holy to the Greeks, Phœnicians and Romans, and to barbarous nations who could only have received it by tradition from Noah and his family.

105. THE ARTIFICIAL DAY, (or variable period of daylight,) the ancient Jews divided at first only into morning, evening, and mid-day; then, probably, into four portions; and afterwards, into twelve parts or "hours;" the last division having been derived from the Babylonians or Chaldeans. The sun-dial of Ahaz is mentioned 2 Kings, xx.

The day-light of the latitude of Judea, varies from a little more than fourteen of our hours to a little less than ten of them. Hence, their *sixth hour* answering to our noon, their *first hour*, according to the time of year, varied from a little after our six, to a little before our eight o'clock: their *third hour* varied nearly from our half-past eight to our half-past nine o'clock; and their *ninth hour* from the half-past two to the half-past three of our afternoon; the hours being of a length corresponding with our own only at the equinoxes.

The night (although varying with the season of the year,) was divided by the Jews, first into three and then into four watches; or the periods assigned to the guards of their city and sanctuary.

The Greeks also derived their mode of computing hours from the Babylonians. The Romans adopted it in imitation of the Greeks. In Roman families of opulence, a slave was in constant attendance on the *clepsydra* or water-clock, to report the hour. "The ancient Romans divided the day and night into twelve hours each, counting from the rising to the setting of the sun, (and from the setting to the rising,) without distinction of season: their hours of the day, therefore, (like those of the Jews,) were longer than those of the night in summer, and shorter in winter * * * * But, under the emperors, they began to perceive that it was inconvenient; and the manner now in use, (with us,) of counting the twenty-four hours in two equal divisions, from midnight to midnight, was gradually introduced."*

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* Sketches of the Domestic Manners of the Romans, p. 91.

12 JUNE XXX DAYS. [WHITE.

LUNATIONS AND PHASES.

First quarter, 7th day, 1h. 17m. morn.
Full Moon, 15th day, 2h. 49m. morn.
Last quarter, 22d day, 11h. 31m. aftern.
New Moon, 29th day, 1h. 59m. aftern.

Mean Noon, and Mean Time, throughout.

M D	☉'s semidiam.	☉'s semid. pass. merid.
1	15′ 47″·1	1^{m} 8^{s}·1
7	15 46·4	1 8·4
13	15 45·8	1 8·6
19	15 45·4	1 8·7
25	15 45·1	1 8·7

M D	Sundays & remarkable days	Sun Ri.	Sun Se.	Clock aft. ☉	☉'s declin.	☾'s declin.	☾ rises & sets.	☾ south.	☾'s hor.par
1		III	VIII	2^{m} 30^{s}	22° n 7′	27° n 54′	10^{h} 17′	1^{h} a 15′	61′ 6″
2		50	6	2 21	22 15	26 30	11 5	2 21	60 34
3		49	7	2 11	22 22	23 17	11 35	3 22	59 48
4		48	8	2 1	22 29	18 44	11 56	4 17	58 55
5		48	9	1 51	22 36	13 19	morn.	5 7	57 59
6	Whit Sunday.	47	10	1 40	22 42	7 28	0 10	5 52	57 4
D		47	11	1 29	22 48	1 28	0 25	6 35	56 15
8		46	12	1 18	22 53	4 s 25	0 34	7 17	55 34
9		46	12	1 6	22 59	10 1	0 46	7 58	55 0
10		45	13	0 55	23 3	15 9	0 57	8 41	54 33
11		45	13	0 43	23 7	19 39	1 11	9 26	54 15
12		45	14	0 31	23 11	23 20	1 29	10 13	54 3
13		44	15	0 18	23 15	26 2	1 53	11 2	53 57
D		44	16	0 6	23 18	27 35	2 26	11 53	53 58
15		44	16	bef. 6	23 21	27 52	rises.	morn.	54 4
16		44	17	0 19	23 23	26 50	10 a 3	0 45	54 15
17		44	17	0 32	23 25	24 34	10 31	1 35	54 32
18		44	17	0 45	23 26	21 10	10 52	2 25	54 54
19		44	18	0 58	23 27	16 49	11 8	3 12	55 22
20				1 11	23 28	11 41	11 21	3 57	55 55
D	Longest day.			1 24	23 28	5 58	11 32	4 40	56 34
22		45	18	1 37	23 27	0 n 7	11 41	5 24	57 19
23		45	19	1 49	23 27	6 22	11 57	6 8	58 7
24	Mids. day.	45	19	2 2	23 26	12 30	morn.	6 56	58 57
25		46	19	2 15	23 24	18 11	0 13	7 47	59 44
26		46	19	2 28	23 22	22 58	0 34	8 43	60 25
27		47	19	2 40	23 20	26 21	1 4	9 45	60 53
D		47	18	2 53	23 17	27 53	1 50	10 51	61 6
29		48	18	3 5	23 14	27 19	sets.	11 59	61 0
30		48	18	3 17	23 11	24 46	9 a 31	1 a 4	60 36

M D	Day increa.	Length of day.	Helioc. long. ♄	Helioc. long. ♃	Helioc. long. ♂	Helioc. long. ⊖	Helioc. long. ♀	Helioc. long. ☿	♄ sets.
1	8^{h} 30^{m}	16^{h} 14^{m}	18 ♐ 13	16 ♏ 5′	29 ♉ 30	10 ♐ 59	5° ♉ 39′	23 ♈ 11	4m 41
7	8 40	16 24	18 24	16 32	2 ♊ 43	16 44	15 15	28 ♉ 37	4 15
13	8 46	16 30	18 34	17 0	5 53	22 27	24 53	6 ♋ 20	3 50
19	8 50	16 34	18 45	17 28	9 1	28 11	4 ♊ 32	11 ♌ 32	3 25
25	dec. 0	16 34	18 56	17 56	12 8	3 ♑ 54	14 11	11 ♍ 22	3 0

12 JUNE XXX DAYS. [WHITE.

LUNATIONS AND PHASES.	M D	☉'s semidiam.	☉'s semid. pass. merid
This space contains the Mean Time of these occurrences; and it is to be remarked, that all occurrences given in *these* pages of the Calendar, are given in Mean Time, and according to our Civil Reckoning.	1 7 13 19 25	1. The half-width of the sun's disc for every 6th day, showing its constant variation in consequence of our variation of distance from him.	2. The exact time this varying half-disc takes to pass our meridian.

M D	Sundays & remarkable days	Sun Ri.	Se.	Clock aft. ☉	☉'s declin.	☾'s declin.	☾ rises & sets.	☾ south.	☾'s hor. par
1 2		III.	VIII						
The Month Days, with Sunday Letter.		The minute of sun-rise and sun-set, shown under the hours given on the first line: thus on the 11th, the sun rose at 45m. past 3, and set at 13m. past 8.		The Equation of time, or difference between the sun-dial and the clock, or the apparent noon and true or mean noon: thus, on the 3d, the clock was after the sun 2m 11s; and on the 16th, 19s before it.	The declination of the sun for every day: thus, on the 1st day be had 22° 7′ north declin.	The declination of the moon for every day: thus, she was north until the 8th, and then, south until the 22nd day.	It is important to observe, that the times specified are those of the moon's setting from new to full, and those of her rising after being full.	This column gives the instant at which the moon *souths*, or comes to the meridian of Greenwich, for every day.	The horizontal parallax of the moon, as she varies her distance from us whilst performing her monthly ellipse: thus, we may learn she was in Perigee, or nearest to us, about the 1st and the 28th, her parallax being then greatest. (See M on p. 18).

M D	Day in. &c	Length of day.	Helioc. long. ♄	Helioc. long. ♃	Helioc. long. ♂	Helioc. long. ⊖	Helioc. long. ♀	Helioc. long. ☿	♄ sets.
1 7 13 19 25	The hours and minutes by which the day has increased or decreased. (We see there is no perceptible decrease from the 21st to the 25th.)		The Heliocentric longitudes of the several primary planets; *i. e.*, their longitudes as they would be seen from the sun's centre: thus, on the 25th ⊖ the earth's is 3° 54′ in Capricorn, we having the sun in Cancer, the opposite sign.						Time of Saturn's setting.

1840.] JUNE. 13

M D	Dayli. begins.	⊙'s h. motion	Logar. dis.o· +	Pl. ☾'s node.	Geoc. long. ♄	Geoc. long. ♃	Geoc. long. ♂	Geoc. long. ♀	Geoc. long. ☿
Every6th d.	Shows, in other months, the beginning of morning twilight.	The hourly apparent motion of the sun in the zodiac; i. e., the rate of angular motion of our earth around him, as she varies her distance from him.		Gives the longitude of the ascending node of the moon for every 6th day.	The longitudes of Saturn, Jupiter, Mars, Venus, and Mercury, as seen from the earth, or rather, from its centre.				

M D	Y D	⊙'s longitude.	☾'s long.	☾'s lat.	♄ Rt.asc.	♃ Rt.asc.	♂ Rt.asc.	♀ Rt.asc.	☿ Rt.asc.
The Day of the Month.	The Day of the Year.	The Sun's place in the Ecliptic for every day.	The Moon's longitude: thus, on the 4th it was 12° 5′ in Leo, and on the 5th, 25° 50′ in that sign.	The Moon's latitude: thus, from the 5th (when she was in her descending node) she had south latitude until the 20th, when she was in her ascending node.	The rig	ht asce planets	nsions for eve The latitudes of the primary planets, which vary very slowly, are given for the 1st and 16th days, up the middle of each column.	of the a ry day.	bove

M D	♃ sets.	♂ rises.	♀ rises.	☿ rises.	♄'s declin.	♃'s declin.	♂'s declin.	♀'s declin.	☿'s declin.
1	The rising or setting of a planet				The declinations of the five primary				
7	is not given in these columns,				planets are given in these columns,				
13	when it takes place in the day-				immediately underneath the columns				
19	time. *m* signifies morning,				situated above, and referring to them				
25	and *a* evening.				severally.				

1840.] JUNE. 13

M D	Dayli. begins.	☉'s h. motion	Logar. dis.☉ +	Pl. ☾'s node.	Geoc. long. ♄	Geoc. long. ♃	Geoc. long. ♂	Geoc. long. ♀	Geoc. long. ☿
1	all day or twilight.	2′23″·6	·006305	1°♓34′	18 ♐ 59	10 ♏ 37	4° ♊ 7′	26 ♉ 22	29 ♉ 52
7		2 23 ·4	·006622	1 15	18 35	10 6	8 20	3 ♊ 42	12 ♊ 32
13		2 23 ·2	·006870	0 55	18 8	9 40	12 31	11 3	25 40
19		2 23 ·1	·007065	0 36	17 42	9 18	16 40	18 23	8 ♋ 23
25		2 23 ·0	·007119	0 17	17 17	9 4	20 47	25 44	20 3

M D	Y. D.	☉'s longitude.	☾'s long.	☾'s lat.	♄'s Rt.asc.	♃'s Rt.asc.	♂'s Rt.asc.	♀'s Rt.asc.	☿'s Rt.asc.
1	153	♊ 10°59′5″	28°♊9	4°n28′	17^h. +	14^h. +	4^h. +	3^h. +	3^h. +
2	154	11 56 32	13♋11	3 43	$12^m 29^s$	34^m 6^s	$11^m 18^s$	42^m 7^s	$59^m 33^s$
3	155	12 53 59	27 52	2 44	12 10	33 44	14 16	47 7	4^h +
4	156	13 51 24	12♌5	1 36	11 51	33 23	17 14	52 9	$16^m 49^s$
5	157	14 48 48	25 50	0 25	11 32	33 2	20 12	57 12	25 43
6	158	15 46 11	9♍7	0 s 45	11 14	32 41	23 10	4^h. +	34 47
D	159	16 43 32	22 1	1 51	10 55	32 22	26 8	$7^m 20^s$	43 59
8	160	17 40 53	4♎34	2 50	10 36	32 3	29 7	12 26	53 18
9	161	18 38 13	16 53	3 39	10 17	31 44	32 5	17 33	5^h +
10	162	19 35 31	29 0	4 18	9 58	31 26	35 3	22 41	$12^m 14^s$
11	163	20 32 49	10♏59	4 45	9 39	31 9	38 2	27 50	21 47
12	164	21 30 6	22 54	4 59	9 20	30 52	41 0	33 0	31 22
13	165	22 27 23	4♐47	5 0	9 1	30 36	43 59	38 10	40 57
D	166	23 24 38	16 40	4 49	8 42	30 21	46 58	43 22	50 31
15	167	24 21 53	28 33	4 24	8 23	30 6	49 56	48 35	6^h +
16	168	25 19 8	10♑30	3 48	8 5	29 52	52 55	53 49	$9^m 27^s$
17	169	26 16 22	22 31	3 2	7 46	29 38	55 54	59 3	18 48
18	170	27 13 35	4♒38	2 6	7 27	29 25	58 53	5^h +	28 1
19	171	28 10 49	16 54	1 4	7 9	29 13	5^h +	$9^m 35^s$	37 7
20	172	29 8 2	29 22	0 n 2	6 50	29 2	$4^m 50^s$	14 51	46 3
D	173	♋ 0 5 15	12♓5	1 9	6 32	28 51	7 49	20 9	54 50
22	174	1 2 28	25 7	2 15	6 14	28 40	10 48	25 27	7^h. +
23	175	1 59 41	8♈31	3 15	5 56	28 31	13 46	30 46	$11^m 54^s$
24	176	2 56 54	22 21	4 6	5 38	28 22	16 45	36 5	20 9
25	177	3 54 8	6♉36	4 43	5 20	28 14	19 44	41 25	28 12
26	178	4 51 21	21 15	5 3	5 2	28 7	22 42	46 45	36 4
27	179	5 48 34	6♊13	5 3	4 45	28 0	25 41	52 5	43 44
D	180	6 45 47	21 23	4 42	4 27	27 54	28 39	57 26	51 12
29	181	7 43 0	6♋33	4 2	4 10	27 48	31 38	62 48	58 29
30	182	8 40 13	21 34	3 4	3 53	27 44	34 36	68 9	65 33

Latitude, 1st d. 1 n 33; 16th d. 1 n 32;
Latitude, 1st d. 1 n 15; 16th d. 1 n 32;
Latitude, 1st d. 0 n 12; 16th d. 0 n 22;
Lat., 1st d. 0 s 57; 16th d. 0 s 23;
Lat., 1st d. 0 s 55; 16 d. 1 n 35;

M D	♃ sets.	♂ rises.	♀ rises.	☿ rises.	♄'s declin.	♃'s declin.	♂'s declin.	♀'s declin.	☿'s declin.
1	2m 45	3m 27	3m 15	3m 24	21°s 28	13°s50′	21°n12′	18°n27′	19°n25′
7	2 20	3 16	3 11	3 32	21 26	13 42	21 59	20 12	22 40
13	1 55	3 6	3 8	sets.	21 24	13 35	22 39	21 37	24 39
19	1 31	2 57	3 9	9 a 14	21 22	13 29	23 11	22 41	25 0
25	1 6	2 48	3 12	9 32	21 21	13 26	23 36	23 22	23 52

34 Jupiter's Satellites. [White.

MAY.	JUNE.	JULY.	AUGUST.
I. Sat. Emers. D. H. M. S. 7 13 4 30 E. 16 9 27 13 E. 23 11 21 33 E. 30 13 15 58 E.	I. Sat. Emers. D. H. M. S. 8 9 39 6 E. 15 11 33 40 E.	I. Sat. Emers. D. H. M. S. 1 9 51 37 E. 24 10 4 31 E.	I. Sat. No eclipses visible at Greenwich this month.
II. Sat. Im. Em. 1 14 28 55 I. 12 8 38 9 E. 19 11 13 25 E. 26 13 48 58 E.	II. Sat. Emers. 20 10 55 44 E.	II. Sat. Neither Im. nor Em. visible at Greenwich this month.	II. Sat. Immers. D. H. M. S. 23 8 10 58 E.
III. Sat. Emers. 9 14 10 22 E.	III. Sat. Im. Em. 14 10 2 54 E. 21 11 56 33 E.	III. Sat. Emers. 27 9 57 16 E.	III. Sat. No eclipses visible at Greenwich this month.

36 SPECULUM PHÆNOMENORUM. [White.

APRIL.		MAY.		JUNE.	
1	☌ ☿ ♂	1	☌ ☽ ♂ in lo. 13h 8m.	4	☌ ☿ ♂ 1h. 38m., ☿ 26′ S.
2	☌ ☽ ♂ in lo. $16^{h}\,16^{m}$.	3	☍ ♃ ☉ 20h. 43m.	5	☿ in ☊
2	☌ ☽ ☿ in lo. $16^{h}\,21^{m}$.	4	☌ ♂ ☉ 3h. 0m.	8	☍ ♄ ☉ 19h. 11m.
5	☌ ♀ ♅	5	☿ elong. max. 26° 18′. W.	9	☿ in perihelio.
7	☌ inf. ☿ ☉ 10h. 15m.	11	♂ in ☊	9	axes } 41″·47 ♄'s ring. } 18·59
7	♀ in aphelio.	14	☌ ☽ ♃ in lo. 21h 9m.	10	☌ sup. ☿ ☉ 9h. 21m.
10	□ ⚴ ☉ 4h. 0 m.	18	☌ ☽ ♄ in lo. 0h 43m.	10	☌ ☽ ♃ in lo. 21° 38′
16	☿ in ♉	18	☍ ♆ ☉ 12h. 46m.	14	☌ ☽ ♄ in lo. 2h. 49m.
17	☌ ☽ ♃ in lo. $21^{h}\,38^{m}$.	20	☉ enters ♊ 13h 13m.	15	☌ ♀ ♂ 15h. 16m. 46′ N.
19	☿ stationary.	27	☌ ☿ ♀ 0h 58m ☿ 29′. S	20	☉ enters ♋ 21h. 48m.
20	☉ enters ♉ 0h. 58m.	29	☌ ☽ ♀ in lo. 17h 49m.	24	♅ stationary.
20	☌ ☽ ♄ in lo. $21^{h}\,11^{m}$.	29	☌ ☽ ☿ in lo. 20h 55m.	25	♀ in ☊
26	☌ ☿ ♀ 10h. 40m. ☿ 39′ S.	30	☌ ☽ ♂ in lo. 8h 30m.	28	☌ ☽ ♂ in lo. 2h. 25m.
26	☿ in aphelio.			28	☌ ☽ ♀ in lo. $13^{h}.51^{m}$.
29	☌ ☽ ☿ in lo. $16^{h}\,21^{m}$.			30	☌ ☽ ☿ in lo. $13^{h}.17^{m}$.
29	☌ ☽ ♀ in lo. $20^{h}\,44^{m}$.				
30	axes } 40″·45 ♄'s ring } 18·09				

34 Jupiter's Satellites. [White.

THE ECLIPSES OF JUPITER'S STELLITES.

MAY.	JUNE.	JULY.	AUGUST.
I. Sat. Emers. D. H. M. S. 7 13 4 30 E. &c. We perceive these occurrences are given in Astronomical time: thus, the first above is equal to our 4m. 30s. past one in the morning of the 8th day.	NB. The *Configurations*, or relative positions of Jupiter and his Satellites, at a certain convenient hour of every day of every month, (when he is visible,) are given, with full explanation, on the 19th page of the month's events in the *Nautical Almanac*.		
II. Sat. Im. Em. The letter I or E, affixed to the time given, signifies *Immersion* or *Emersion*; (see def. 59).			
III. Sat. Emers. NB. The IV. Satellite does not enter Jupiter's shadow during the year 1840.			

36 SPECULUM PHÆNOMENORUM. [White.

APRIL.		MAY.		JUNE.	
2	Moon in conjunction with Mars, 16m. past 4 A.M. of the 3d. instant.	3	Jupiter in opposition to the sun at 43m. past 8 A.M. of the 4th instant.	5	Mercury in his ascending node.
7	Mercury at his inferior conjunction, *i. e.*, nearly between us and the sun, 15m. past 10 P.M.	5	Mercury at his greatest elongation, as a morning star.	8	Saturn in opposition 11m. past 7 A.M. of the 9th, and therefore on our meridian at midnight.
10	Pallas's quartile aspect, or three signs from the sun, 4 P.M.	11	Mars in his ascending node, *i. e.*, crossing our ecliptic to make north latitude.	9	Saturn's ring, (41½″ long and 18½″ wide,) this is about its greatest apparent opening.
16	Mercury in his descending node, or crossing the ecliptic to make S. latitude.	20	Sun enters Gemini at 13m. past 1 A.M. of the 21st.	10	Mercury at his superior conjunction, *i. e.*, on the other side of the sun.
30	Saturn's ring, 40½″ long and 18$\frac{1}{10}$″ wide.			10 14	The moon in conjunction with Jupiter and Saturn at the hours given.
				24	The Georgian appearing to have no motion among the stars about this time.
				25	Venus in her ascending node.

106. **Nebula**, (Lat., a mist or fog,) is a term applied to patches of pale light, of which some are visible to the naked eye, and multitudes by means of the telescope.

Some of these are easily resolvable into stars: others cannot be resolved by the best telescopes. Thus, the stars of the white speck "*Præsepe*," in the constellation Cancer, can be separated by an ordinary night-glass; whilst one of similar appearance to the naked eye, in the Girdle of Andromeda, retains its nebulosity in the most powerful instruments. A hazy light surrounds some stars, which are on this account termed nebulous.

107. **Galaxy, or Milky Way**, (γαλαξιας), is a nebulous Zone, of unequal width, encircling the celestial sphere, and found to derive its light from the myriads of stars which compose it. It probably constitutes our firmament, the brighter stars of our sky being our nearest neighbours, and our sun and its system being situate about midway between the confines of this zone. The scattered nebulæ seen in other portions of the sky, are conceived to constitute similar firmaments.

LIST OF CONSTELLATIONS.

The object in introducing a list of Constellations in this place, being to facilitate the knowledge of their positions on the globe and in the heavens, the author has deviated from the arrangements usually made, judging that, with the assistance given in the appendix, a catalogue of this form is more likely to answer the purpose. (See "*Rhymes on the Constellations.*") The Signs of the Zodiac have already been given separately in Definition 70.

CONSTELLATIONS,

Parts of which coincide with the Equinoctial, with their extents in Declination.

	No. of Stars.		Extent.	Remarkable Stars.
Pisces	113	The fishes (string and western fish)	30 N. to 0 N.	(α in the string.)
Cetus	97	The Whale (neck)	10 N. to 24 S.	Mencar 2.
Orion	78		20 N. to 10 S.	Rigel 1, Betelgeux 1, Bellatrix 2

	No. of Stars.		Extent.	Remarkable Stars.
*Monoceros	31	The Unicorn (shoulder & back)	10 N. to 15 S.	
Hydra	60	The Water-serpent (head)	7 N. to 34 S.	Cor Hydræ, 1.
*Sextans	41	The Sextant	8 N. to 8 S.	
Leo Major	95	The greater Lion (hinder feet)	30 N. to 2 S.	Regulus or Cor Leonis 1, Deneb 2.
Virgo	110	The Virgin (shoulder & feet)	20 N. to 12 S.	Spica Virginis 1, Vindemiatrix 2.
Libra	51	The Balance (the beam)	5 N. to 19 S.	Zubenich Meli 2.
Serpentarius or Ophiucus	74	The Serpent-holder (Body)	22 N. to 30 S.	Ras Alhagus, 2.
*Taurus Poniatowski	7		10 N. to 0 N.	
*Aquila and Antinöus	71	The Eagle and Antinous	15 N. to 8 S.	Altair or Atair 1.
Aquarius	108	The Water-bearer (head)	5 N. to 30 S.	Scheat 3.

CONSTELLATIONS NORTH OF THE EQUINOCTIAL,

Between east portion of *Pisces* and the North Pole, are:

Andromeda	66		Mirach 2, Almaach 2.
Cassiopeia	55	Lady in her chair	Schedir 3.

Between the Head of *Cetus* and North Pole.

Aries	66	The Ram	α Arietis 2.
Triangulum (Major and Minor)	11	The Triangle	
*Musca	6	The Fly	
Caput Medusæ and Perseus	59	Head of Medusa and Perseus	Algol 2, Algenib 2.
*Tarandus	10	The Rein-Deer	

Between the Belt of *Orion* and North Pole.

Taurus	141	The Bull (horns of)	Aldebaran 1, Pleiades, Hyades.
Auriga	66	The Waggoner	Capella 1.
*Camelopardalis	58	The Camelopard	

Between Mid-back of *Monoceros* and North Pole.

Canis Minor	14	The less Dog	Procyon 1.
Gemini	85	The Twins	Castor 1, Pollux 2.
Lynx	44	The Lynx	

Between Head of *Hydra and Sextans* and North Pole.

Cancer	83	The Crab	Acubene 4.
Leo Major	95	The greater Lion	Regulus, or Cor Leonis 1, Deneb 2.

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* Those marked thus (*) are modern constellations.

	No. of Stars.		Remarkable Stars.
Leo Minor	53	The less Lion	
Ursa Major	87	The greater Bear	Dubhe 1, Alioth 2, Benetnach 2.
Between Shoulder of *Virgo* and North Pole.			
Coma Berenices	43	Berenice's Hair	
Canes Venatici	25	The Hounds ..	Cor Caroli.
*Cor Caroli	3	Charles's Heart	
Between Beam of *Libra* and North Pole.			
Serpens	64	The Serpent	
Boötes	54	....	Arcturus 1, Mirach 3.
Corona Borealis	21	The Northern Crown	Alphacca 2.
Part of Draco..	80	The Dragon ..	Rastaben 2.
Ursa Minor....	24	The less Bear ..	Stella Polaris 2, (Pole-star.)
Between Head of *Serpentarius* and North Pole.			
Hercules (and Cerberus)..	113	Hercules and the three-headed dog	Ras Algethi 3.
Draco (head of)	80	The Dragon....	Rastaben 2.
Between *Aquila and Antinöus* and North Pole.			
Delphinus	18	The Dolphin	
*Vulpecula et Anser	37	The Fox and the Goose	Vega or Wega, 1.
Lyra..........	22	The Harp	
Cygnus........	81	The Swan	Deneb Adige, or Arided 1.
Between Head and Urn of *Aquarius* and North Pole.			
Equulus (head)	10	The little Horse	
Pegasus(head of)	89	The Flying Horse	Markab 2, Scheat 2.
*Lacerta	16	The Lizard	
Cepheus	35	The husband of Cassiopeia and father of Andromeda	Alderamin 3.

"The general aspect of the southern circumpolar region, is, in a high degree, rich and magnificent, owing to the superior brilliancy and larger development of the Milky Way, which, from the constellation of Orion to that of Antinöus,* is in a blaze of light, strangely interrupted, however, with vacant and almost starless patches, especially in Scorpio, near a Centauri and the Cross; while to the north it fades away pale and dim, and is, in comparison, hardly traceable."—*Sir John Herschel.*

"As our merry little ship approached the far-famed Cape of Good Hope, I often remained on deck after the watch was out, feasting my eyes on the sight of constellations known to me before only by name, * * * * * * the Peacock, with a forehead glowing like Aldebaran * * * * the huge ship Argo, ranging across the southern heavens, with a star of the first magnitude flaming in the blade of one of her oars. * * * * But of all the Antarctic Constellations, the celebrated Southern Cross, is by far the most remarkable * * * This constellation, being about thirty degrees from the South Pole, is seen in its whole revolution; and accordingly, when off the Cape, I have observed it in every stage, from its triumphant erect position, between sixty and seventy degrees above the horizon, to that of complete inversion, with the top beneath and almost touching the water."—*Captain Hall's Fragments*, 2d. Series, Vol. 2.

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* *i. e.* all the southern portion of the Galaxy.

CONSTELLATIONS SOUTH OF THE EQUINOCTIAL,

Between *Pisces* (tail of west Fish) and the South Pole are:

	No. of Stars.		Remarkable Stars.
*ApparatusSculptoris, (or Praxitelis,) the tools of the Sculptor or of Praxiteles	16		
*Phœnix	13		
*Toucan	9	The American Goose	

Between Head of *Cetus* and South Pole.

*Formax Chemica	14	The Furnace	
Eridanus (pt. of)	84	The River Po ..	Acherner 1.
*Horologium ..	12	The Clock	
*Reticulus Rhomboidalis	10	The Rhomboidal Net	
*Hydrus	10	TheWater-snake	

Between *Orion* and South Pole.

*Sceptrum......	4	The Sceptre	
Lepus	19	The Hare	
*Cela Sculptoria	12	The Engraver's Tools	
*Columba Noachi	10	Noah's Dove	
*Equuleus Pictorius..........	8	The Painter's Easel	
*Dorado (or Xiphias	7	The Sword Fish	
*Mons Mensæ ..	30	TheTableMountain	

Between Shoulder of *Monoceros* and South Pole.

Canis Major ..	31	The Greater Dog	Sirius 1.
Argo Navis	64	The Ship Argo	Canopus 1.
*Piscis Volans ..	8	The Flying Fish	

Between Head of *Hydra and Sextans* and South Pole.

Part of Hydra			
*Machina Pneumatica	3	The Air Pump	

Between Hinder Leg of *Leo* and South Pole.

	No. of Stars.		Remarkable Stars.
Crater	31	The Cup or Goblet............	Alkes 3.
Part of Hydra			
*Chamæleon	10	The Chameleon	

Between the Shoulder of *Virgo* and South Pole.

Corvus	9	The Crow	Algorab 3.
Part of Hydra			
Centaurus	35	The Centaur	
*Crux	6		
*Chamæleon	10	The Chameleon	

Between the Beam of *Libra* and South Pole.

Lupus	24	The Wolf	
*Circinus	4	The Compasses	
*Triangulum Australe	5	The Southern Triangle	
*Apus, or Avis Indica	11	The Bird of Paradise	

Between West Shoulder of *Serpentarius* and South Pole.

Scorpio	44	The Scorpion ..	Antares 1.
*Norma, or Quadra Euclidis ..	12	Euclid's Square	
Ara	9	The Altar	
*Octans	43	The Octant	

Between *Taurus Poniatowski* and South Pole.

*Scutum Sobieski	8	Sobieski's Shield	
Sagittarius	69	The Archer	
Corona Australis	12	The Southern Crown	
*Telescopium ..	9	The Telescope	

Between *Antinöus* and South Pole.

Sagittarius	69	The Archer	
*Microscopium	10	The Microscope	
*Indus	12	The Indian	
Pavo..........	14	The Peacock	

Between Head and Urn of *Aquarius* and South Pole.

Capricornus ..	51	The Goat	
Piscis Australis	24	The Southern Fish	Fomalhaut 1.
Grus	13	The Crane	

ILLUSTRATIVE EXTRACTS

FROM CAPTAIN BASIL HALL'S FRAGMENTS OF VOYAGES AND TRAVELS.

LONGITUDE.

"Although it is, undoubtedly, in the fine-weather regions of the globe that the picturesque or poetical beauties of the moon are most felt and seen, her highest utility to seamen lies in the tempestuous latitudes beyond the tropics. Many a stout-souled mariner's heart beats with anxiety and apprehension as he steers his bark round the stormy capes which bound Africa and America, or, worse still, into the British Channel, before a hard south-wester, and prays for the moon to rise. Even to this hour, though many years have passed over my head since then, I remember the joyous feeling with which I blessed the coming of her pale light, when my poor ship was entangled with icebergs off Cape Horn, in the long and dreary nights of the Antarctic July."—Vol. III. 3rd. Series, p. 255.

"But the genuine triumph of the moon, after all, consists in her power, when duly propitiated, of conducting her votaries round the world, and leading them into unknown seas and bays, and far from land, with as much certainty as if they were sailing close to their own shores, familiar to their eyes from infancy."—P. 261.

"'The moon is the hand of a great Greenwich clock, seen all over the world, with which you compare the chronometer, to see how it differs and how it goes. You then compare it with the sun as clock of the place. Having by another separate observation determined the latitude.'

"In practice it is easy to press the moon into our service, and make her act as the hand of a Greenwich clock in the sky. The moon, as every one knows, moves, like all the planets and satellites, from west to east, amongst the stars, and performs the complete circuit of the heavens once in every month; that is to say, she moves to the eastward through the heavens at the average rate of about 13 degrees a day, or somewhat more than half a degree an hour. Thus her apparent motion amongst the stars is about one minute of space in two minutes of time; and this, which is a rate of movement distinctly perceptible even to the naked eye under some circumstances, is always observable with the instruments in use at sea. The consequence is, that whenever the sky is clear, and the moon up, we can ascertain, at any given moment of time, by actual observation, her exact place in the heavens relatively to the sun or planets, or stars lying in her path. We then refer to the Nautical Almanac, an Ephemeris in which the moon's place has been previously computed by astronomers, and there we discover the Greenwich time at which it has been predicted that she will reach the point in the heavens we have observed her to occupy, at the moment of 'taking the lunar,' as it is called. Having likewise ascertained what was the 'ship's time' at the same instant, by other observations made on board, we ascertain their difference by subtracting one from the other, (precisely as in the case of the chronometer), and we arrive at the difference of longitude between the ship and Greenwich."—P. 266.

LATITUDE.

"In practice, we have merely to watch till the sun, moon, planets, or some one of the numerous bright objects, whose places in the heavens have been well ascertained, comes to the meridian of the ship; we then measure, by a sextant,* its altitude or angular elevation above the horizon, and having applied to that angle the correction due to the star's known distance from the pole, we come at the latitude required. I need not repeat that, were the star which we observe situated actually in the pole, no such correction would be necessary. This may be repeated with other stars throughout the night, though many navigators content themselves with observing the sun's altitude at noon for the latitude. I used always to make my middies determine the ship's latitude in their respective night-watches, and write the result on the log-board, as a current matter of duty.

"The exact moment of noon, it may be thought, is the only one at which the sun's altitude ought to be taken for determining the latitude; and so in strictness it is. But the change of altitude during about half an hour before, or half an hour after noon, is so small, and its rate of variation so well known, that if the ship's time, which is generally known near enough, be only carefully noted by watch, while repeated observations of the sun's altitude are taken, during the twenty minutes before and after noon, the latitude may be determined with nearly as much precision as if the exact meridian observation had been obtained."—P. 270.

"I have seldom remained at sea twenty-four consecutive hours, in any climate, without obtaining the latitude, if I wished anxiously to know the ship's place.

"It is very curious, but very true, that the extreme simplicity of the methods of ascertaining the latitude at sea, both at night and in the day time, compared with the operose and delicate operations necessary for finding the longitude, give to the longitude an importance which it is by no means entitled to claim relatively to the latitude. One is exactly as material as the other, with this great difference in practice, that if the sky be clear, the latitude may easily be determined half-a-dozen times during every hour of the night, whereas the longitude by lunars can be gained only when the moon is above the horizon, and when she is at a particular age. By the help of a chronometer, indeed, the longitude may be corrected almost as often as the latitude; and navigators are much too remiss in using stars for the purpose of determining their time at ship. If advantage be taken of the half hour, or three quarters of an hour, after the sun is well below the horizon, or before he rises again in the morning, the altitude of stars may be observed with great precision by using the inverting telescope of the sextant; and if during the same period the meridian altitude of two or three stars be observed, the ship's place, both in latitude and longitude, may be settled very accurately."—P. 272.

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* "Sextant," an instrument with two small reflectors, one of them attached to a moveable index, which, being shifted by the hand, is contrived to show the angular distance from the horizon, &c., at which the reflected star is situated.

"We were running for the British Channel before a hard south-west gale, and it was of considerable importance that we should reach some port in England without delay, for we were not only charged with despatches, but were very short of provisions and water. The only chronometer I had on board happened not to be very good, and the sky had been so completely overcast for more than a week before, that we could take no lunars. Thus I felt uncertain of my longitude, to the extent of a degree at least; and all who have tried the experiment know what a nervous thing it is to run in for the land, in the dark, and in stormy weather, when the ship's place is not correctly known. But I felt exceedingly loath to lose so magnificent a wind, before which we spun along at the rate of ten knots,* under a reefed foresail and close-reefed main-topsail. As long as daylight lasted I felt very confident and bold about the matter; but as the night closed in, the doubts and difficulties of the Channel navigation crowded round my thoughts, and almost determined me to bring the ship to,† and wait for the dawn. After poring for a long while over the chart, however, I satisfied myself that if, by any means, I could be sure of keeping in the latitude of 50¾°, or within ten or a dozen miles on either side of that parallel, I should have clear ground to run over for three degrees of longitude at least, greatly within which I felt sure that the error of my chronometer must lie. But how was I to determine this point with any degree of certainty in such weather? The sky had not showed a patch of blue as large as my hand for several days, and though the sun had been seen through the clouds occasionally, we had not succeeded in catching a meridian observation.

"In this dilemma I bethought me of the pole-star, proverbially the mariner's friend, and having fixed my sextant by the cabin light, at the angle about which I knew the latitude must give the altitude of the pole, I cast my boat cloak over my shoulder, and went on deck. There I stationed myself on the larboard‡ side of the quarter-deck, with the instrument sheltered from the rain and spray under the cloak, and grasped in my right hand, while I kept my eye fixed on that part of the heavens in which I hoped, at some momentary opening, to detect the bright star of my night's fortunes. I had to wait more than an hour before there occurred any thing like a chance, by which time my limbs had become cramped and stiffened by the constraint of one posture, while my eye ached and throbbed with its vain attempts to pierce the thick courses of clouds sweeping past.

At last I did get sight of the star, for three or four seconds, and though it glimmered so faintly through the mist, that it could hardly have been identified as Polaris, even by Sir James South himself, I knew by its altitude that it must be the object I was watching for. The horizon was but a shabby one, indistinctly seen in the dark, and hacked by the topping waves like the Sierra Morena. Nevertheless, I succeeded in bringing the star in contact§ with the edge of the sea in the north, where, fortunately, there chanced at that moment to occur a faint gleam in the lower atmosphere.

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* Ten miles per hour.

† To cease sailing.

‡ The left side.

§ *i. e.*, by moving the index of the sextant, and its attached reflector, to see the reflected image of the star in the direction of the horizon.

"I ran below, read off the angle, computed the latitude, and found it not more than twenty miles from what I had expected, and quite enough to keep the ship safe for some hours' run. But as one insulated observation, made under such circumstances, could not be depended upon, I hastened on deck again, and presently—that is in less than half an hour—caught a second glimpse of my friendly lighthouse* in the sky. The result agreed with that of the first observation within ten miles, and of course gave me greater confidence.

"Still, as the night was dark, the horizon bad, and the observations both to the north, I could not rely upon them to the extent which was desirable, I may say indispensable, in running for the Channel in such a night and at such a rate. So I cast about to fish for a star on the southern side of the zenith, and was rejoiced to find that a brilliant planet, either Jupiter or Saturn, I forget which, came to the meridian before midnight. On deck I went again, sextant in hand, and although I possessed no very certain means of telling 'the time at ship,' I watched for the planet, and caught it for a moment not very far from the meridian, as I knew by the 'compass bearing.' With a flushed cheek, and hand trembling so that I could scarcely hold the pencil, I worked out the latitude, and found it to differ from the mean of the two results by the pole-star rather less than twenty miles. A second cast at the planet, after it had passed the meridian a few minutes, gave, when properly reduced, a latitude which differed only five or six miles from the first. Putting all these observations together, I felt quite certain that the ship's path lay within the limits marked along the chart as a safe track, and having given orders to shake out a reef, pressed forward as fast as masts, yards, and hull would bear.

"The ever-welcome dawn at length appeared, and not long afterwards I had the infinite satisfaction of discovering from the deck, the well-known Lizard Point, with its two light-houses, streaming with the night's rain, one above the other, and shining brightly in the morning sun."—P. 275.

GULF STREAM.

"We had the benefit of a slight drain of current in our favour, from being still within the north-western limit of the mighty Gulf Stream—that prodigious water-course, the largest in the world, which, after sweeping out of the Indian ocean, doubling† the Cape, and traversing the whole region of the south-east trade wind, enters the gorge between Africa and the Brazils, crosses the Equator, passes the Caribbee Islands, and scours the Gulf of Mexico; then gushes off, through a huge sluice, by the Straits of Florida, and, gradually expending its gigantic strength as it washes the shores of the United States, finally deposits its load—the washings of a hundred seas, and of ten thousand rivers—in the shoals of Nantucket, and the well-known Banks of Newfoundland."—Vol. II. 1st. Series, p. 84.

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* The Pole-Star.

† *i. e.* Going round.

EFFECTS OF THE GULF STREAM.

"When I was mate* of His Majesty's ship Leopard, I was placed in charge of the identical ship which carried Jerome Buonaparte and his family to Europe, and selected for that purpose from being considered the fastest sailer out of Baltimore. I certainly never saw so perfect a model of a merchant vessel, or one more commodiously fitted up. I was, of course, prodigiously proud of my new and beautiful command; but had soon more important matters to attend to in the navigation of the ship, the difficulties of which may be easily explained.

"When we parted company from the Leopard, we were within a few days' sail of the coast of America, and may then have been a hundred leagues or so to the north-westward of Bermuda; consequently, still within the influence of the Gulf Stream, already alluded to as sweeping, in a north-eastern direction, along the shores of the United States. I was ordered to take my pretty charge to Bermuda, and proceeded to the southward accordingly. Foul winds, however, detained us for several days in the Gulf Stream, for the set of which current such an ample allowance was made, that when we reached the latitude of Bermuda, 32½ N., it seemed almost certain that we were some thirty or forty miles to the westward of the island, that is, between it and the coast of America.

"From the land of Bermuda being low, it is not easily got sight of; and the whole cluster of islands being of small extent, they are often missed by navigators steering, as they conceive, directly for them. To those, indeed, who are provided with time keepers, there is no danger in following this direct method; for these instruments are now so admirably constructed, that an error in longitude which would carry a navigator past Bermuda, without seeing it, is, now-a-days, very unlikely to occur. Ships, however, which have not the advantage of a chronometer, and consequently may not be sure of their longitude, generally find it prudent to run into the latitude of the island, and then steer along that parallel till they come in sight of their object. Most people are probably aware, that the latitude is an element in navigation almost at all times very easily determined, at least with sufficient accuracy for the purpose now alluded to. The longitude, as every mortal must have heard, is, or rather was, the grand stumbling-block in a sailor's way; and it will readily be understood, of what essential importance it must be to a ship, when running along a parallel of latitude, in search of a mere speck on the ocean, like Bermuda, that there should be no mistake as to which side of the island she really is upon. For if, in point of fact, the ship shall happen to be on the eastern side of the island, but, owing to some error in the reckoning, her captain believes that she is on the western side, he will naturally steer east along the parallel of latitude, instead of west, as he ought, of course, to do; and thus he will go on increasing his distance from the island, instead of shortening it.

"This curious case was precisely mine. The Gulf Stream, as it eventually appeared, had carried us eighty or ninety miles farther to the eastward than I had made allowance for, although an ample daily set in that direction was given her.* The superficial velocity of this mighty current, it seems, is occasionally accelerated or retarded by the prevalence of hard gales. At all events, whatever might be the cause of this unusual increase in the rate of the stream, it carried me so far beyond my mark, that when I reached the parallel of 32½ N., I supposed myself in longitude 65½ W., that is, about forty miles on the western or American side of Bermuda. As the wind was blowing from the east, of course I struggled hard to beat up against it, from supposing that my port lay to windward. It was fortunate this breeze was not blowing from the west, as I shall proceed to show."—P. 89.

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* *i. e.* Senior Midshipman.

"On the day I reached the latitude of Bermuda (32½ N.), I fancied the ship must certainly be on the western side of the island; the sun, however, happened not to be in distance,† as it is called, and, of course, no lunars could then be observed. Having, therefore, still nothing to trust to but the dead reckoning,‡ we, of course, continued beating all the morning to the eastward, under the full persuasion that Bermuda was in the wind's eye, due east of us, instead of being, as it really was, due west, on our lee-beam.§

"As the night approached, the sky became beautifully clear, and shortly after sunset I got my sextant to work. Before the twilight was ended, and the horizon too faint to admit of the altitudes being taken with accuracy, I had observed four or five sets of lunars. No time was lost in working out, when, lo and behold! the longitude, instead of being 65½ W., as I made it by dead reckoning, appeared to be little more than 64 W., or some ninety miles farther to the eastward; thus showing that, although, as we supposed, we were thirty miles from the land, it was on the opposite side of the island from that on which we had imagined ourselves to be!

"What was now to be done? For, although on board the flag ship, where the accuracy or inaccuracy of a midshipman's lunars did not matter a straw, I had indulged in the usual presumption of fancying myself rather an expert observer, I was now filled with doubt and anxiety. All the ordinary allowances for the set of the Gulf Stream had already been made, and it was hardly to be conceived that in a week or ten days there should have occurred an error of a degree and a half. It appeared far more likely that some gross mistake had been committed in the figures of the computation, or in my mode of observing the lunars, than that such a huge augmentation to the strength of the current should have occurred at this particular moment.

"The American captain, who, like most commanders of ships of that class sailing from the United States, was an admirable navigator, and a very shrewd, obliging, and gentlemanlike person, happened to be so ill that he could not possibly come on deck, to make observations to corroborate mine. But he was able, though in bed, to go over the computations, the result of which, in his hands, agreed so nearly with what I made it, that he, at least, had no doubts of their accuracy, and recommended me at once to put the helm up, and steer to the westward. I had not confidence enough, however, in my own handiwork, for a decision so material to the success of the voyage. In short, I could not force my unpractised imagination to conceive that an island, which I had so much reason to suppose lay due east of me, could possibly be hit upon by steering due west."—P. 94.

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* *i. e.* In the daily reckoning.

† *i. e.* The moon was not of convenient age.

‡ The calculation without astronomical observation, by a consideration of the wind and the ship's rate of motion.

§ That part of the ship farther from the wind.

"So, to work I went again, with my observations for the longitude. After all the adjustments of the sextant had been carefully examined, a new gang of lunars was taken, some with the same, and some with other stars, but all of them with a degree of attention which, if measured by the depth of interest felt in the result, I am not sure I have ever bestowed upon any similar course of observation since. Half of the distances I gave over to my friend, the captain, to compute, while I set about calculating the rest. After a time we exchanged computations, without communicating each other's results, till all were finished, and then we laid them side by side. The agreement amongst the whole observations was so near to one another, and corresponded also so closely with those taken earlier in the evening, that I could no longer have a doubt as to what should be done. About midnight, with a throbbing heart, and a mind filled with the most painful anxiety, I bore up,* and, as we had a fresh breeze, spanked along merrily to the west. It was necessary, of course, in running in such a perilous neighbourhood, to keep a very bright look out; for although Bermuda, on its eastern side, is pretty clear of coral reefs, and we were quite certain of our latitude, it was not the sort of place to approach incautiously. When the moon went down, therefore, we shortened sail, but continued still slipping along at the rate of four or five knots, till morning.

"When the eastern sky first began to give some faint promises of a dawn, I felt my anxiety mount to a pitch scarcely bearable, and I kept peering with the night-glass into the gloom which still hung over the horizon in the supposed direction of Bermuda, as if my eagerness to see what was hid beyond, could have brushed away the night any quicker. When, at last, the day broke, and the well-known cliffs of St. David's Head, topped with dark green cedars and lighter-tinted orange trees, stood pleasantly up ahead of us, at the distance of a league and a half, I could have shouted for joy."—P. 97.

"I was not a little amused by finding we had reached the island before our own ship,† and, a few days afterwards, I had the satisfaction of rowing on board to report myself, before she anchored. The compliments paid to our success were due, it must be owned, to the sextant so opportunely sent to me; for, unless the dead reckoning had been checked by lunar observations, we might have been kept at sea a month; and, as the ship was short of provisions, serious consequences must have ensued."—P. 100.

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* i. e., altered, and in this case reversed, the ship's course.

† i. e., "The Leopard."

PROBLEMS.

SECTION I.

RELATING TO THE EARTH'S SURFACE AND TO ITS DIURNAL ROTATION.

PROBLEM I.

TERRESTRIAL GLOBE.

To find the Distance between two Places.

Repeat the following definitions :—*

Circle (F, p. 1) ; Centre (G, p. 1) ; Angle and Degree (L, p. 2) ; Globe or Sphere (B, p. 8) ; Great Circle and Small Circle (D, p. 8) ; Terrestrial Globe (def. 8) ; Equator (def. 13) ; Brazen Meridian (def. 20) ; Quadrant of Altitude (def. 48).

Rule.—If the two places be on the Equator, count the degrees between them on that line ; if, when one of the places is brought to coincide with the graduated surface of the Brazen Meridian, the other be likewise cut by it, count the degrees of distance between them as shewn by that graduation. If otherwise, lay the 0 of the Quadrant of Altitude upon one of the places, and that portion of its graduated edge which will coincide with the other place will give the degrees of distance. The English miles of distance may be found by multiplying the degrees so found by 69½; or nearly, and more readily, by multiplying them by 70.

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* The appropriate definitions, &c., are given before the rule of each problem. It is desirable that they should be committed to memory ; but, in any case, they should be duly considered before working the questions of the problem.

1. Find the distance in degrees of a great circle between Quito and Chatham Island, (Easternmost of the Galapagos) ?

2. Between Quito and the island of Saint Thomas, Gulf of Guinea) ?

3. Between the mouth of the Fish River, or Angra Pequena, (S. W. coast of Africa) and Lake Tchad, (of Bornou, its interior) ?

4. Between Land's End and St. Helena ?

5. Between Philadelphia and Carthagena, (N. of South America) ?

6. Between Madrid and the Orkneys ?

7. Between Lisbon and Washington,
Petersburgh and London,
Calcutta and Pekin,
Cape Chidley, (Labrador) and Upsal, (Sweden)
how many English miles ?

8. Suppose a line to descend to the Earth's centre from Port Royal, Jamaica, and another line to descend to meet it, at the Earth's centre, from the Island of Bermuda; what number of degrees would measure the angle made by these two straight lines ?

9. Suppose a ship in Port Royal, Jamaica, and another at the Island of Bermuda; how far distant, in degrees of a great circle, must the two Stars be to which these two ships are pointing their masts, at any given instant ?

10. How many degrees in the heavens would the mast of a ship describe by its pointing, if it could steadily sail by a straight course from the south coast of Owhyhee to Otaheite, (Tahiti) ?

11. What is the breadth (in English miles) of Africa, from Cape Verd to Cape Guardafui ?

12. What difference is there in English miles between this width of Africa, and the shortest distance between London and Jamaica ?

13. If a star be over my head, at any given instant, at Blackheath, how many degrees in the heavens is that star separate from it, which is *then* overhead to my friend at Alexandria ?

14. How many degrees, also, another star which is vertical, at the same instant, to other friends on the North East shore of Lake Erie?

15. Find the extent of Europe, in English miles, from North Cape (Lapland), to Cape Matapan (the Morea)?

16. Suppose the following to be the track of an outward-bound East India ship, and that the several portions of her course could be straight lines, how many English miles would she travel?

I. From the Lizard Point to Madeira?

To take in wine, and fruit, and vegetables.

II. From Madeira to the Canaries?

"Shortly after leaving Madeira, a ship may expect to meet the Trade Winds."

III. From the Canaries to the Cape Verd Isles, (*i. e.* San Antonio, the Westernmost)?

"On first reaching the Trade-wind, it will be found to blow very nearly from due East." (But the Southward course, amongst the Canaries, and thence to "the Cape de Verds," is easily made with this side-wind.)

IV. From off San Antonio, to that portion of the Equator equally distant from Cape Palmas and Cape St. Roque; "the opposite shoulders of Africa and South America?"

"As the ship proceeds southward, (*i. e.* towards and beyond the Cape Verd Isles) the wind draws gradually round from the east to north-east, and eventually to the north-north-east, and even to north at the southern margin of the north-east Trade-wind."

V. Thence off Cape St. Roque?

"The Equatorial limit* of the Trade-wind varies considerably with the season of the year," (being sometimes 3° north of the Equator, and sometimes as much as 13° north of it). "Before reaching 'the Line,' the Navigator will almost always be met by the south-east Trade-wind." * * * "On first encountering the south-east Trade-wind, an outward-bound ship is obliged to steer much more to the westward than she wishes to do, in consequence of the wind blowing so directly towards the Equator," (*i. e.* so nearly from the south.)

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* The intervening region between the limits of the two Trade-wind belts, viz. that of the Northern, and that of the Southern Hemisphere, is called by Captain Basil Hall, (whose lively descriptions we have quoted above,) "the purgatory of the outward-bound voyage. —Calms are met with, and, occasionally, violent tornados, or squalls, which, in a moment, tear every rag of canvas from the ship's yards. For several hours at a time, also, rain falls down in absolute torrents."

VI. From Cape St. Roque due southward, until as far south as the Cape of Good Hope?

"As the ship proceeds onwards, however, and makes a little more southing, the wind will haul more and more round, from the south to south-east; then east-south-east; and, eventually to east, at the southern limit of the Trade-wind."

VII. Thence to the Cape of Good Hope?

"The great object of an outward-bound ship is to get far enough south,"—to ensure the westerly winds, which generally prevail for many degrees south of the southern Trade-wind belt; as they do northward of the northern one.

VIII. Thence by the Mauritius, and Ceylon, to Madras?

"In the Indian Ocean, from about 28° south of the Equator to the Equator, the S. E. Trade-wind blows pretty constantly; but, in the Arabian Sea, and the Bay of Bengal, there are certain periodical winds called *Monsoons*, which from April till October blow from S. W.; and from the N. E. from October till April." *

PROBLEM II.

TERRESTRIAL GLOBE.

To find the Latitude of a given place.

Repeat the following definitions:—

Equator, (def. 13); Poles of a Circle, (F p. 8); Poles of the Earth, (def. 10); Latitude of a Place, (def. 15); Parallels of Latitude, (def. 16); Divisions of the Brazen Meridian, (def. 21); Hemisphere, (def. 32).

RULE.—Let the Globe be so placed, as that the pupil may conveniently look over its surface, when standing eastward of its South Pole; which may be a little depressed below the point marked "South" on the wooden Circle which supports it. If the proper semicircle of the Brass Meridian be uppermost, the Northern Hemisphere will now be to the right hand, which must always be used for northern places; the left hand being reserved for southern ones.

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* Riddle's Navigation, p. 291.

Having thus arranged the Globe, if the given place be north, bring it to the Brazen Meridian with the *right* hand; if the given place be south, with the *left* hand; and the degree coinciding with the place, will be its north or south distance from the Equator, or its Latitude.

N. B. The degrees on the brass meridian of a globe of twelve inches width are seldom subdivided; but the pupil may easily allow for half-degrees. On some of the larger globes the degrees are divided into *thirds;* on others into *quarters.*

1. Find the latitude of the north point of the Island Gilolo, (N. E. of Celebes)?

2. Find the latitude of Amboyna, (E. of Celebes)?

"At the equator we find the natives of the Spice Islands, the clove and nutmeg tree, pepper and mace."*

3. Find the latitude of Trincomalee?

"Cinnamon bushes clothe the surface of Ceylon."†

4. Find the latitude of Mocha?

"In Arabia 'the Happy' we find balm, frankincense, and myrrh, the coffee-tree, and the tamarind; but in these countries, (*i. e.* of such latitude), at least in the plains, the trees which decorate our more northerly climes are wanting."

5. Find the latitude of Astracan?

"In the thickets to the west of the Caspian Sea, we have the apricot, citron, peach, and walnut."

6. Latitude of Valencia, Palermo, and Oporto?

"In the same latitude, (viz. that of the thickets of the Caspian,) in Spain, Sicily, and Italy, we find the dwarf-palm, the cypress, the chestnut, the cork tree. The orange and lemon trees perfume the air with their blossoms. The myrtle and the pomegranate grow wild among the rocks."

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[*] The quotations in this, and the succeeding Problem, are from Whewell's Bridgewater Treatise.

[†] This is not strictly correct. The plant grows wild in the woods; but its cultivation is confined to the S. W. angle, where it covers 17,000 acres; and the fragrance is perceptible at a very considerable distance from the shore.

7. Latitude of Cape Horn, and of Edinburgh ?

The general temperatures of the Northern and Southern Hemispheres differ very considerably. South America, towards its southern extremity, has a climate scarcely habitable, owing to the severity of its frosts.

8. Latitude of Buenos Ayres, of St. Helena, of Montreal, and of Botany Bay ?

The temperature of a country is always affected by its elevation above the sea; the distribution of the neighbouring sea and land; the height of its mountains; the nature of its soil, &c.

9. Latitude of Strasbourg, of London, and of Brussels ?

"We cross the Alps, and we find the vegetation which belongs to Northern Europe, of which England affords an instance: the oak, the beach, the elm. The elm-tree seen in Scotland, and in the north of England, is the *Wych* elm."

10. Find the latitude of St. Petersburgh, and of Mainland, (Orkneys) ?

"The forests again change their character. In the northern provinces of the Russian Empire are found forests of the various species of fir: the Scotch and Spruce firs, and the larch. * * * * *
In the Orkneys no tree is found but the hazel, which occurs again on the northern shores of the Baltic."

11. Find the latitude of Tornea, and of Stockholm ?

"The 'hoary,' or cold alder, makes its appearance north of Stockholm. The sycamore and the mountain ash accompany us to the head of the Gulf of Bothnia."

12. Find the latitude of North Cape, Iceland, and of North Cape, Lapland ?

"Near to, or within the Arctic Circle, we yet find wild flowers of great beauty: the mezereum, the yellow and white water-lily, and the European globe-flower. When these fail us the Reindeer-moss still makes the country habitable for animals and man."

The finest pastures of Iceland are said to be in the northern parts of the island.

13. Find the latitude of the Falkland Islands, (eastern point), and contrast its distance from the equator with that of London ?

Such was the inhospitable nature of the climate of the Falkland Isles some years ago, that they were totally unfitted for the habitation of man. A mere bog, with mountains beaten with almost perpetual storms.

PROBLEM III.

TERRESTRIAL GLOBE.

To find the Difference of Latitude of two places.

Repeat the Definitions given for Problem II. Repeat also, Zones, def. 71.

Rule.—If both places be in the same hemisphere, subtract the less latitude from the greater. If one be in the northern and the other in the southern hemisphere, the sum of their latitudes is the difference required.

"The cultivated vegetables which form the necessaries or luxuries of human life, are each confined within limits, narrow, when compared with the whole surface of the earth; yet, almost every part of the earth's surface is capable of being abundantly covered with one kind or other of these. When one class fails, another appears in its place. Thus corn, wine, and oil, have each its boundaries."

1. Find the difference of latitude between Dublin and Lassa? (N.B. Both places *north.*)

"Wheat extends through the old Continent from England to Thibet; but it stops soon in going northwards, and is not found to succeed in the west of Scotland. Nor does it thrive better in the Torrid Zone than in the polar regions. Within the Torrid Zone, wheat, barley, and oats, are not cultivated, excepting in situations considerably elevated."

2. Difference of Latitude between Teneriffe and Bourdeaux. Bourdeaux and the Cape of Good Hope. (N.B. One place *north,* and the other *south.*)

"In both hemispheres, the profitable culture of the vine ceases within 30° of the Equator; unless in elevated situations, or in islands, as Teneriffe."

3. Difference of latitude between Charleston (South Carolina,) and Turin—Between Genoa and S. Point of Java—Between Cape St. Mary (S. Point of Madagascar,) and Bencoolen.

"In the north of Italy, west of Milan, we first meet with the cultivation of rice. Rice extends all over the southern part of Asia, wherever the land can be, at pleasure, covered with water. In great part of Africa millet is one of the principal kinds of grain."

4. Find the difference of latitude between Halifax (Virginia), and the mouth of the Volga.

Between Rio Janeiro and the north point of Niphon (Japan).

"Cotton is cultivated to latitude 40 in the *new* world, but extends to Astracan in latitude 46 in the *old*."

For the same products we must search several degrees nearer to the Equator in the American Continent than in the Old World. This is owing to the difference of temperature alone, the soil of America being naturally as rich as that of any portion of the earth.

5. Find the difference of latitude between Canton and Nankin.

The tea plant is seldom cultivated farther north than the 30th degree of latitude; and thrives best between that and the Torrid Zone.

6. Find the difference of latitude between Manilla (Luzon, of the Philippines,) and Owhyhee.

Between N. of Owhyhee and the southernmost of the Feejee Islands.

The bread-fruit tree first appears in the Manillas, and "thence extends its benefits through innumerable islands in the Indian and Pacific Oceans."

7. Find the difference of latitude between Delhi and Cayenne.

Between the south point of Florida and Port Royal, Jamaica.

"The sugar cane, the plantain, the mulberry, the betel nut, the indigo tree, the tea tree, repay the labours of the cultivators in India and China, and several of these plants have been transferred with success to America and the West Indies."

PROBLEM IV.

CELESTIAL AND TERRESTRIAL GLOBES.

To find the Declination of a given Star, and the places which pass directly underneath it, as the earth rotates.

Repeat the following:—

Celestial Globe, (def. 11); Fixed Stars, (def. 4); Constellations, (def. 6); Greek Alphabet, (page 24); Equinoctial, (def. 14); Declination, (def. 17); Read over "Rhymes on the Constellations," (Appendix).

Rule.—Bring the given star to the upper semicircle of the brass meridian of the celestial globe, and the degree coinciding with the star will show its north or south declination.

Place the thumb-nail (of the right or left hand accordingly, see Prob. II.) upon that part of the brass meridian of the terrestrial globe which agrees in number and position with the declination of the star; and cause this model of our earth to rotate toward you, as you stand eastward of its south pole. The places which pass under the thumb-nail will be those daily passing under the given star, which, on this account, is said to culminate vertically.

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1. Find the declination of "Castor," (*α* of Gemini); and note down some of the principal places which daily pass exactly underneath it.

Answer. 32½° north declination. Places, Nankin, (nearly,) Lahore, Ispahan, &c., &c.

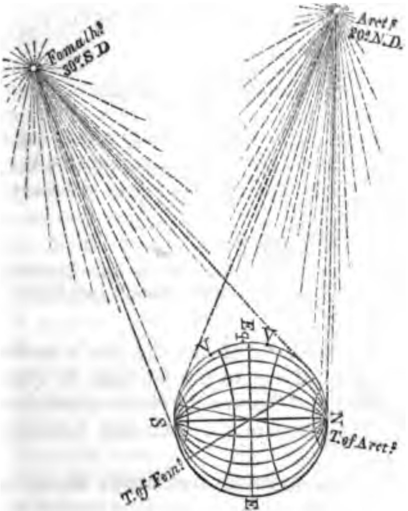
2. Find the declination of "Rigel," (*β* in the heel of Orion); and name any particular islands, and other places,

to the inhabitants of which it appears to pass vertically, or nearly vertically.

3. Find the declination of δ of Orion, and the places that daily have it in their zenith.

Also γ of Virgo . . . . . . ditto
α of Boötes, ("Arcturus") . ditto
α of Canis Major ("Sirius") . . ditto
β of Perseus ("Algol") . . ditto
Brightest of the Pleiades (in Taurus) ditto
γ of Crux (near the South Pole) . ditto
α of Ursa Minor ("Pole Star") . ditto
α of Scorpio ("Antares") . . ditto

PROBLEM V.



Remark.—Every heavenly body, at any instant of time, sheds its direct beams over an exact half of our earth's surface; and, in the absence of overpowering rays, (as of the sun or moon,) may be seen, in clear weather, by all the inhabitants of that half-surface.

But the *latitudes* of the regions contained in that half-surface, will depend upon the heavenly body's *declination*. Thus, whilst a star, which, like δ of Orion, is in the Equinoctial (*i. e.*, without declination, and therefore vertical to our Equator,) sheds its beams from pole to pole, and is viewed in *all* latitudes; the beams of a star situated northward of the Equinoctial, (as *Arcturus* 20° N.D., drawn in the preceding figure,) must fall short of the south pole to an extent equal to its north declination; and accordingly, be perpetually invisible to the inhabitants of a certain southern portion of our globe.

But, for the same reason, the beams of that star will shine *over* the north pole, (see "T (terminator) of Arcturus" in the figure,) and can never be absent from a corresponding region of the northern hemisphere.

The same remarks apply, *vice versâ*, to stars having south declination; such as *Fomalhaut*, (see figure.)

TERRESTRIAL GLOBE.

The declination of a star, &c., being given, (or the latitude in which it culminates vertically,) to find to what places it is constantly above the horizon, and where it cannot rise.

Repeat the following:—

Terminator, (def. 30); "Rhymes on the Constellations," six verses, (Appendix); Read "Double Stars," (see Index); "Variable Stars," (see Index).

Rule.—Elevate the pole to the star's declination; or, which is the same thing, to the latitude in which it culminates vertically; and the wooden circle of the globe will then represent the terminator, or constant boundary of that star's beams.*

Cause the globe to rotate (eastward) on its axis, and it will be seen that all places not more distant from the elevated pole than the given star is from the equinoctial, cannot lose its rays; whilst those within a corresponding distance of the other pole, cannot receive them. Note down those places.

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* It will be useful to rest a small coin, as a fourpenny-piece, upon the brazen meridian, with its centre coinciding with the declination, to represent the star.

1. Find those places to which the following stars never rise, and those places also where they are perpetually above the horizon.

α of Eridanus, "Achernar," (between the body of the Whale and the South Pole), 58° S. D.

Here, elevating the South Pole 58°, the wooden circle of the globe represents the terminator or boundary of the latitudes which the star's rays can reach, and I find by turning the globe, that whilst this star is always above the horizon of the southern portions of Africa, America, and New Holland, and of the whole of New Zealand, &c., it is not seen from the extreme north of Africa and Arabia; and is, of course, always absent from all Europe and the greater part of North America and Asia.

α of the Southern Fish, "Fomalhaut," (near the tail of Cetus)	30¼ S. D.
β of Perseus, "Algol" (in the head of Medusa)	40 N. D.
δ of Cetus	½ S. D.
α of Lyra ("Vega")	38½ N. D.
β of Orion ("Rigel")	8½ S. D.
α of Crux	62¼ S. D.

2. How far over the North Pole can the rays of Capella, (β of Auriga, N. D. 45¾,) diffuse themselves; and at what places can Capella never be seen to set?

3. How far short of the South Pole do Capella's rays reach; and from what places on our earth can Capella never be viewed?

4. If the Pole-star (α of Ursa Minor,) were exactly at the Polar point, from which part* of our earth would it never be seen?

5. The Pole-star is about 1½° from the Polar point, or has a little less than 88° 27′ of north declination: at what places, therefore, is it some time above the horizon, (although only at a little elevation,) besides those north of the Equator?

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* *i. e.* disregarding the effects of refraction.

PROBLEM VI.

TERRESTRIAL GLOBE.

Having the declination of a star, and the place to which it is appearing to pass vertically, to find all those places to which it is at that instant rising; and what portion of the time of each diurnal rotation of our earth, certain of these places severally spend in that star's beams.

Repeat the following:—

Diurnal Arc, (def. 33); Planets, (def. 1); Hour Circle, (def. 25); Sidereal day, (def. 83); Learn remaining verses of "Rhymes on the Constellations," (Appendix.)

Rule 1. Elevate the pole to the latitude in which the star is vertical, or, which is the same thing, to the declination of the star; and bring the given place at which the star is vertical to the brass meridian. Then, the places along the western edge of the terminator will be those which are rising into that star's light.

2. Set the Index* of the hour circle to the time of the place at which the star is vertical, and give the globe its eastward rotation. It will be found that if the star be of the northern hemisphere, the southernmost place will first arrive at the eastern edge of the terminator; but that if the star be a southern one, that place most northern will first set out of its beams. Count the hours† elapsed, as each place arrives at the eastern edge of the terminator, and record them.

1. Each day, at the instant that Capella is vertical at Venice, I find that the cities of Mexico and Quito, St. Vin-

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* If the hour-circle be under the brass meridian, it is to be turned until the graduated edge of the brass meridian cuts the hour.

† The hours must be counted, especially if the hour-circle have only one row of figures.

cent, (near the bay of the Virgin, N. of California,) and the Isle of St. Francisco, (north of the Island of St. Catherina, east coast of South America,) are rising into its beams. Supposing it to be 10 o'clock at Venice, in how many hours, from that time, will these several places set out of Capella's beams?

Here, elevating the North Pole to 45½°, (*i. e.* to the latitude of Venice), I bring Venice to the brass meridian, and set the hour circle to 10, the time given: All places now above the wooden circle, or terminator, have Capella above the horizon. Keeping the globe steady, I seek along the western edge of the terminator, and note down, the principal places rising into Capella's light, of which places, it is evident, that since Capella is a northern star, *St. Francisco*, the place most south, will first have passed through its beams. Next, turning the globe eastward, I find that when St. Francisco has arrived at the eastern edge of the terminator, to have Capella setting in the west, the index has traversed about 7¾ hours; but that *Quito* is not in this condition until about 12 hours have passed—Mexico, after somewhat more time—St. Vincent, California, after much more time, &c. These portions of time are to be given.

2. [June 20th, 12 at night], γ of Draco, (Etanin) 51½° N. D. is vertical at Blackheath: What places are at that instant rising into its rays; and of these places, what several portions of time do Chatham Isle (one of the Galapagos), Cuzco (Peru), the Island of St. Catherina, and the Island of Tristan de Conha, daily spend in those rays?

3. On 25th March, "Antares" (*α* of Scorpio) is vertical to Cape St. Mary (S. point of Madagascar), at 11 o'clock at night: to what places is it rising; and of these places, how long will the following, severally, have it above their horizon? viz. Anglesea, St. Mary's (East I. of the Azores), and the south point of the Island of Chiloe (S. of Chili).

4. When ε of Orion's Girdle is vertical to the Galapagos at a certain hour, (say 1 o'clock in the morning), it is rising to the following places:—Tanaga, (one of the Aleouskie Islands); Isle of St. Pierre, (11° N. lat.); the Feejee Islands; Cape E. New Zealand: How much of the sidereal day do they severally spend in its beams?

5. On 3rd May, 1840, the beautiful planet Jupiter will be in the zenith of any place 15° south when it is midnight at that place. What places will be rising into its beams when it is vertical just north-east of Otaheite; and of

these places, how long will the following severally continue in his light? viz. Cape Elizabeth, (the N. point of Saghalien,) Great Lekeyo, (Loo Choo Isles); N. E. point of Celebes, (adjoining the Sea of Celebes); and Sandy Point, or north-west Cape, (westernmost of New Holland).

6. When γ of "Crux" is vertical to Cape Horn, 28th Sept. at noon, or on any other day at any other time, it is rising to the following places: — Savannah River; Bay of St. Magdalena, (S. W. of California); Christmas Isle, (a little north of the Equator); the principal of the Feejees; Erronan, or Erromango,* (south Island of the New Hebrides); Glass-House Bay, (New Holland); Nuyt's Islands, (S. coast of New Holland). What are the diurnal arcs of this star at these several places?

PROBLEM VII.

Remark.—It is hoped that the pupil will now have perceived, that what is called the "rising" and "setting" of a heavenly body, and its daily westward course, are occasioned solely by the eastward revolution of our earth about its axis. The portion of time occupied by this apparently westward passage of a heavenly body, and which is called its "Diurnal Arc," varying in any certain latitude with the declination of the star; or, in the case of any certain star, with the latitude of the place; but being, invariably, 12 hours for every star to the inhabitants of the Equator, and twelve hours at every place if the star is in the Equinoctial. The apparent altitude of any heavenly body, or its elevation above the horizon of any place, at any certain time after its rising, is, in like manner, dependent upon latitude and declination; and, corresponding exactly with the *elevation* of that place in its light, may thus be found for any hour by the Terrestrial Globe, if the time of the star's rising, &c., be known.

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* It was by the inhabitants of this island, that the devoted Missionary, Williams, was killed, 22nd November, 1839.

TERRESTRIAL GLOBE.

Having the declination of a star, to find at what altitude the star appears to the inhabitants of a given place, after the lapse of a certain portion of time from its rising.

Repeat the following :—

Complement, (N p. 2) ; Sensible Horizon, (def. 27) ; Rational Horizon, (def. 28) ; Zenith distance, (def. 40) ; Altitude, (def. 44) ; Repeat " Rhymes on the Constellations," (Appendix).

Rule.—Elevate the pole to the North or South declination of the star, to exhibit the latitudes of the surface which rise into its light : bring the given place to coincide with the western edge of the terminator, and set the index of the hour circle to any hour, as a mark. Next, turn the globe eastward until the index have passed over the portion of time given ; and the elevation of the proposed place above the terminator, will be the altitude at which the star appears above the horizon. Find these degrees of elevation, by attaching the quadrant of altitude to the declination of the star in the zenith of the brass meridian, and making its graduated edge pass across the place.

Since the quadrant of altitude is thus attached to the zenith of the place where the star is vertical, its pivot may represent the star ; and the number of degrees between this pivot and the given place, shows the zenith distance of the star.

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1. At what altitude does Arcturus (Dec. 20, N.) appear above the horizon of London, an hour and a half after it has risen ?

Here elevating the North pole 20°, I bring London to the western edge of the terminator ; then, setting the hour-circle and turning the globe until the index has traversed 1½ hour, I find by the quadrant that London is — degrees above the terminator.

2. At what altitude does this star appear at Barbadoes 3 hours after rising, and 9 hours after rising?
At Cape Horn* 2 hours after rising?
At S. point of Iceland 9 hours after rising?

3. What is the altitude of Rigel, in the heel of Orion, (8½ S.) 4 hours after rising at Blackheath; and what its altitude when it has been above the horizon 9 hours at that place?

4. When Sirius (α of Canis Major, 16½ S.) has been above the horizon 1¾ hours at the several places following, at what altitudes will it appear: London—Edinburgh—Jamaica, (Kingston)—Otaheite—Buenos Ayres—Cape of Good Hope?

5. At what elevation does α of Lyra, (38½ N.) appear after it has been above the horizon of Madrid 3¼ hours, and 14 hours: Cape East, New Zealand, 2 hours, and 5 hours; Owhyhee, (N. point of) 5 hours; Pekin, 9 hours, and 14 hours?

PROBLEM VIII.

CELESTIAL GLOBE.

A certain star being in the zenith of a certain place, to find the amplitude of any stars rising or setting there; and the azimuth, at that instant, of any stars that may then be above the horizon.

Repeat the following:—

Zenith, (def. 38); Nadir, (def. 39); Amplitude, (def. 46); Azimuth, (def. 45); Compass, (def. 36); Variation of the Compass, (def. 37).

Rule 1. Elevate the North or South Pole, according to the latitude of the place; or, which is the same thing, according to the declination of the star passing vertically.

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* Cape Horn is the south point of an island.

2. Bring the given star* to the brass meridian, and it will now be in the zenith; and the innermost circle of figures on the wooden horizon, will show the degrees of amplitude from the east or west at which any star is found at its rising or setting in that latitude.

3. For the azimuth, attach the quadrant to the meridian so that the bevelled edge of its nut may coincide with the zenith and the star; then the graduated edge, made to pass through any proposed star, will cut the horizon at its azimuth or bearing from the north or south, as shown by the second circle of figures.

1. At Cape Comorin (S. of Hindostan), on a certain night, when *α* of Aquila ("Altair" 8° north dec.) is in the zenith, what is the amplitude, or distance from the east, of *α* of Aries, then just rising; and what the azimuth, or bearing from the south of "Fomalhaut" (*α* of the Southern Fish), which had risen more than two hours before?

Here, elevating the N. Pole 8°, and bringing Altair to the brazen meridian, and consequently to the zenith, I find that *α* of Aries is rising $22\frac{1}{3}$° N. of E.; and by affixing the quadrant to the zenith, I find that its graduated edge cuts Fomalhaut in azimuth —° S. towards E. as shown by the marking on the horizon.

2. What also, at that instant, was the azimuth or bearing from the north, of Arcturus, then within three quarters of an hour of its setting?

3. At Blackheath, (lat. $51\frac{1}{2}$°) I observed *γ* of Draco ("Etanin") vertical: What was the amplitude of *β* (in the west shoulder of Virgo,) then just setting; and what, at that instant, was the azimuth of the following stars:—

$$\left.\begin{array}{l}\text{“Antares,” (}\alpha\text{ of Scorpio)}\\ \text{“Arcturus,” (}\alpha\text{ of Boötes)}\end{array}\right\}\text{ S. towards W.}$$

β of Ursa Major, (one of "the Pointers") N. towards W.
"Schedir," (*α* of Cassiopeia) N. towards E.
"Markab," (*α* of Pegasus) S. towards E.

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* The pupil must remember that the rotation of the Terrestrial Globe, representing the rotation of our earth, and being eastward, that of the Celestial Globe, a representation of reversed motion apparent only in consequence of the earth's rotation, must be invariably *westward*.

4. At sea, near the Marquesas (lat. 10 S.), when the brilliant star, *a* of Virgo, was passing in my zenith, I observed that "Canopus," (*a* of Argo Navis) and "Pollux," (*β* of Gemini) were both setting: what are their several amplitudes there; and what, also, is that of (*a* of Lyra), "Vega," which then had just risen between north and east?

5. At the Cape of Good Hope, (lat. 34½ S.) on the evening of the same date, but some hours before, my friend likewise had watched the rising of *a* of Lyra and the setting of Canopus and Pollux, in order to ascertain the variation of the compass there: what were their amplitudes at his station?

6. And what amplitudes have those stars at Buenos Ayres: and what azimuth, when *a* of Lyra is rising, have any stars of the 1st magnitude which are above the horizon at that place?

PROBLEM IX.

Remark.—It has been explained (def. 36), that the Mariner's Compass is a representation of the sensible horizon, and that its 32 points are graduations in degrees of this horizon: what is called the "*bearing*" of one place from another, is its situation with regard to the horizon of the latter place as indicated by these compass points.

But since the horizon is a *plane* (D p. 1), and the earth's surface convex, the *true bearing* of any place situated considerably beyond my horizon is not shown by the compass, unless the place be on the same meridian semicircle: *i. e.* unless it lie due North, or due South; for the same reason that the leaf of this book, or any sheet of paper, cannot be made to coincide with the convex surface of the globe.

Suppose an individual to travel duly west from London, following the pointing of his compass card, (corrected for variation):—as he constantly changed his horizon he would as constantly keep the same angle, or bearing, with every meridian he crossed, and thus truly trace out our parallel of latitude. For a certain distance he would be *apparently*, as well as *really*, west of me; but, prosecuting his way half round that parallel, he would arrive at the Fox Islands (on the opposite meridian), and to point out his station, I must direct my finger *duly north*. Hence, any distant place having apparent position toward our west, must lie considerably *south* of his station, or of our parallel. The Galapagos themselves, (situated on the Equator), have due west for their apparent bearing.

On some globes, but few, the true bearing of places is traced by means of *rhumb-lines;* a kind of spiral curves,* which accommodate themselves to the sensible horizons of the various places through which they pass by making equal angles with their meridians, like the course of a traveller continually guided by his compass.

Note.—Since the earth is but a point when considered with the celestial sphere, and our sensible horizon therefore corresponding with the rational one in the sky, (See B, p. 10), the compass, which describes bearings on the one circle, serves to describe them on the other; and the azimuth or bearing of any star in the sphere, (being reckoned on the rational horizon), coincides, at any instant, with the apparent bearing of the place in the zenith of which it is shining.—(See the next two Problems).

TERRESTRIAL GLOBE.

A place being given, with the Angle of Position or apparent bearing of another place of given distance, to find that place.

Read the foregoing remarks. Repeat the following:—

Angle of Position, (def. 47); Meridians, (def. 22); Markings of the Horizon, &c. (def. 31); Cardinal Points, (def. 35).

RULE.—Bring the given place to the brass meridian, and elevate the pole to its latitude; then will the given place be uppermost, and the wooden circle represent its rational horizon. Affix the quadrant of altitude to the zenith of the place, and bring its graduated edge to cut the horizon in that point of the compass given as the bearing. If the distance be given in English or Geographical miles, bring them into degrees, and find their complement (N p. 2): Under this complement on the quadrant will be the required place.

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* Called in Mathematical language, *Loxodromic.*

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1. What city is that which lies E. S. E. from Edinburgh, and is distant from it 25° ?

Elevating the pole to the latitude of Edinburgh, and bringing that city to the meridian, I screw the quadrant over it, and make the graduated edge cut E. S. E. on the horizon; then, at 25° distance, or under 65°, its complement on the quadrant, I find Constantinople.

2. What place is that which is distant 45° from Cape Town, and considerably westward of it, in pointing towards which, I must direct my finger 96° from the true south of my horizon?

3. What remarkable Cape is that distant from Cape Town exactly 60½°, and in pointing towards which, my right hand must make with my left 40°, when the latter is directed southward in the plane of my meridian?

4. The North Magnetic Pole is stated, by Captain Ross, to be in 70¼° of north latitude: give (nearly) the longitude of this spot by the bearing of 24½° W. which is the variation of the compass from our Greenwich meridian?

5. What city is that which is situated 5140 English miles from London, and which lies within 15° of the equator, but which has an "angle of position" of 90°, or apparently bears due E. of London?

Conversely—6. Cherson (at the mouth of the Dnieper) lay under the edge of the quadrant when the last answer was found; and it may have been inferredthat the Indian city sought must have the apparent bearing of 90° from Cherson also.—Find that bearing from Cherson?

7. What is the distance and apparent bearing of Jamaica from London?

8. If, in Madrid, a person direct his right arm along the plane of the meridian towards the north, and his left towards Philadelphia, how many degrees of the horizon will there be between these pointings of his hands?

PROBLEM X.

TERRESTRIAL AND CELESTIAL GLOBES.

A place being given at which a certain star is culminating vertically, to find those places where certain other stars are vertical at that instant.

Learn the Note just preceding Problem IX. Learn Poles of Celestial Sphere, (def. 12); Repeat Quadrant of Altitude, (def. 48).

RULE 1. Bring the given place to the brazen meridian, and elevate the pole to its latitude: this will bring the given place uppermost, and cause the wooden circle of the globe truly to represent the rational horizon of the place.

2. Bring the star which is vertical at the given place to the brazen meridian, and elevate the pole to its declination: this will bring the star to the zenith.

3. Screw the quadrant of altitude to the zenith, and, making the graduated edge of it coincide with the other star, note down its zenith distance, and its azimuth, or "bearing" from the north or south of the horizon.

4. Apply the quadrant, in like manner, to the Terrestrial Globe, (screwing it to the brass meridian over the given place), and the place corresponding in degrees of distance and apparent bearing will be the place required.

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1. When γ of Draco ("Etanin"), is vertical to the inhabitants of London, where is α of Lyra ("Vega") vertical?

2. Where are the stars in the head of Delphinus then nearly vertical?

Here, having arranged the globes by Sections 1 and 2 of the Rule, I find by Sections 3 and 4, that the azimuth and zenith distance of α of Delphinus, agree with the distance and apparent bearing of that narrow part of the Red Sea which is W. of Sana.

3. Where is " Spica" (α of Virgo), then vertical?

4. When " Cor Caroli" (in the Dogs of Boötes) is vertical to the Observatory at Pekin, where is "Regulus" (α of Leo Major) culminating vertically?

5. When " Cor Caroli" is just south of the zenith of Madrid, where are Regulus and "Deneb" (β of Leo) vertical?

6. At Madrid, on the 20th April, at 11 o'clock, I observed that " Cor Caroli" was culminating in my zenith: over whose heads was " Castor," (α of Gemini), then brightly shining in my north-west?

7. At sea, 8th March, half past 7, p. m. (in lat. 16½° S.) at a time when the inhabitants of the Marquesas saw Canis Major due south of them, I observed the mast pointing directly to " Sirius," (α in Canis Major): near what islands, and how situated, was the remarkable southern constellation " Crux," at that time?

8. At the same instant where were the stars in the head of " Aries" vertical?

9. Where, then, the stars in the head of the " Lynx," (then culminating low in *my* north,) vertical?

10. Where, at that instant, was " Vega" (α of Lyra) in the zenith, although not above my horizon?

11. Where was the Pole Star at that instant; that is, how situated with respect to the Polar point?

PROBLEM XI.

TERRESTRIAL GLOBE.

A place being given, to find what other places lie in the same plane with that place and with both of the Poles of our Earth, and consequently with its whole axis.

Repeat the following:—

Axis of the Earth, (def. 9); Plane of the Meridian, (def. 19); Meridians, (def. 22); Longitude of a Place, (def. 23); Plane, (G, on page 9).

Rule.—If there be a meridian line drawn on the globe,* passing through the place, note down the places lying likewise on it for the answer; but, if not, make the poles coincide with the wooden circle, and bring the given place to the graduated edge of the brazen meridian; then, all places coinciding with the brazen meridian will be the places required.

Note.—Those coinciding with the *under* semi-circle of the brazen meridian, although in the same plane, may, in this instance, be left unnoticed.

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1. What places lie in the same plane
with Land's End, } and with the whole axis of the earth?
„ the Island of Chiloe,
„ Barbadoes,

2. When γ of Virgo is vertical to that part of the east coast of Africa which is on the Equator, what places have that star exactly north of them, and what places have it exactly south?

3. When any place passes northward or southward of Aldebaran, (in Taurus), on the night of Christmas day, it is 10 o'clock; what places have, all of them, 10 o'clock when that star is vertical at the Island of Guadaloupe?

4. Some hours after this occurs, in consequence of the eastward rotation of our globe, this star will appear in the zenith of the inhabitants of the Ladrones: where will it then be 10 o'clock, as well as at those islands?

5. When it is 3 o'clock in the morning, or any other particular time of day, at Cape Horn, where is it the same time of day?

6. When the sun is on the meridian of St. Helena, and

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* It would be well if the pupil were always to conceive of the "meridians" drawn on the Terrestrial Globe, as circular disks of paper, each of them passing through the solid body of the Globe, and each crossing all the others in the whole length of the axis; their edges peeping out at the circumference of the Globe and appearing as lines, only because of having been rubbed down to coincide smoothly with its surface.

it is, consequently, noon at that island, at what other particular places is it also noon?

7. When, on any day, three hours have elapsed since St. Helena had the sun on the meridian; and it is, therefore, 3 in the afternoon there; to what other places also is it 3 in the afternoon?

8. Seven hours before that place or Gibraltar had the sun on the meridian, or mid-day; and when, consequently, it was 5 o'clock in the morning at those garrisons, to what other places was it 5 o'clock in the morning?

9. On a certain night the moon was exactly full when culminating in the zenith of the western point of Jamaica: to what places did she cast shadows duly northward, and to what places did she cast them duly southward, at that instant; and since it must have been midnight at these places and Jamaica, in what parts of the world was the sun culminating at the same time?

PROBLEM XII.

Remark.—The imaginary plane passing through London, Havre, &c., and the whole axis of our globe; and which, if continued, will cut through the middle of the Aleouskie Islands, the easternmost of the Fejees, and a point very near the "East Cape" of New Zealand, is a standard plane of British Geographers; viz. that from which they reckon eastward and westward.

When London is brought to coincide with the brass meridian, the graduated surface of its whole circle represents an extension of this plane—(See next Examples). It will be evident to the intelligent pupil, that if, *after so placing London, we move the surface of the Globe either eastward or westward,* the plane, or rather *semi-plane,* in which London is situated, and which so passes along the axis, will be *inclined,* at a certain *angle,* to one exactly similar, pointed out in like manner by the brass meridian as *now coinciding with it.* This inclination of the meridian plane of any place to that of London, (*our* first meridian), is called the *longitude* of that place. The angle, or inclination of the two planes, might be measured on *any* of the parallels of of latitude; but, for convenience sake, its degrees are reckoned on the Equator, which is graduated for this purpose.

When, by the rotation of our earth, the plane of the meridian of any place is brought to coincide with the sun, it is *mid-day* or 12 at noon to that place. Hence the clocks, or sun-dials, of all places having the same meridian plane, will correspond at 12; and, therefore, at any other hour.

But, since all these semi-planes are moving *eastward*, those places which belong to that half-surface of our earth which is *east* of our London meridian, and which, consequently, *precede* us in receiving the noon-day sun, will have their clocks *faster* than ours; whilst those on the *western* half-surface, and which, consequently, we ourselves precede, will have their time-keepers, or their sun-dials, *slower* than ours, in proportion as they are situated westward.

Hence, a correct time-keeper, transferred from the place in which it has been correctly *set*, will give the longitude of the place at which it is consulted, by showing the contrast of its *time*; and consequently, the degrees of *inclination*[*] to the east or west of its own meridian.

TABLE TO BE LEARNED BY ROTE.

15° of longitude	one twenty-fourth of the circumference.
15° ———	one hour.
1° ———	four minutes of time.
1′ ———	four seconds of time.

2 times 15..30	6 times 15.. 90	10 times 15..150
3 — 15..45	7 — 15..105	11 — 15..165
4 — 15..60	8 — 15..120	12 — 15..180
5 — 15..75	9 — 15..135	

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[*] We use this term because, as the pupil will see a little farther on, the *length* of a degree of longitude varies with the latitude.

TERRESTRIAL GLOBE.

To find the Longitude of a given place, and its time as compared with that of London or Greenwich.

Repeat the following :—

First Meridian, (def. 24) ; Solar day, (def. 84) ; True, or Mean Noon, (def. 86). Learn the Tables just preceding.

Rule.—Bring the given place to coincide with the graduated surface of the brass meridian, and it will show, as in the last Problem, the plane of its meridian :—The number of degrees of longitude is shown where this plane cuts the Equator. Turn those degrees into minutes of time by multiplying by 4, or into hours, by dividing by 15. If the place be to the east of London, add that time; if to the west subtract it.

If the Pupil stand, as he ought, S. E. of the Globe-surface, he will reckon *towards* him for east, and *from* him for west, longitude. The Equator of a twelve-inch Globe is generally subdivided only to half-degrees : that of a larger Globe to quarter-degrees, or minutes of time.

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1. What is the longitude of Mecca,
,, ,, of Malta,
,, ,, of Ascension Island,
,, ,, of Mexico,
,, ,, of Port Jackson,
,, ,, of Cape Horn,
,, ,, of E. point of Porto Rico,
and how much will clocks, correctly set by the sun at these places, differ from the clocks of Greenwich; and whether will they be, behind or in advance of Greenwich clocks ?

2. If, after sailing down our coast to Lowestoff, its most eastern town, I cross the country to Land's End, its most western point, how do I find my London watch,

if performing correctly, when comparing it with the clocks at both of these places?

3. Are the clocks of the following places faster or slower than those of London, and how much:—Petersburg—Cape Town — Philadelphia—Barbadoes — St. Helena—Madras—Batavia—Otaheite?

4. Each day of the year differs from the day which precedes it with respect to the period at which any fixed star appears on the meridian. On the night of 28th January, Sirius (the Dog Star) comes to the meridians of the following places when their clocks are striking ten: what hours will the clocks of London be showing at these several instants?—Vienna—New York—Calcutta—Lisbon—Dublin—Port Royal, (Jamaica).

PROBLEM XIII.

CELESTIAL GLOBE.

To find the Latitude in which a certain Star rises or sets at the instant that another certain Star is culminating.

Repeat the following:—

Sidereal Day, (def. 83); Astronomical and Civil Reckoning, (def. 82); Right Ascension, (def. 52); Sidereal Clock. (def. 53).

RULE.—Bring the star given as culminating to the brass meridian, and elevate or depress the pole until the other star coincides with the eastern or western part of the horizon. Then the number of degrees on the brass meridian from the elevated pole to the horizon, will show the latitude. N.B. It is important to take the point in the centre of the star's rays for the star's place.

1. In what latitude did I observe Arcturus on the meridian, when Antares (α of Scorpio) was rising?

Here, by bringing Arcturus to the brass meridian, and arranging the poles until Antares is coinciding with the eastern part of the horizon, I find that declination 60° N. is in the zenith; and that, consequently, the North Pole is elevated 60°.

2. When α of Lyra (Vega) is on the meridian, Algol (of Perseus) is rising, what is the latitude?

3. —— Altair (α of Aquila) on the meridian, β of Leo Major setting, what is the latitude?

4. —— Fomalhaut (of Piscis Australis) on the meridian, Rigel rising, what is the latitude?

5. —— α of Crux on the meridian, α of Columba setting, what is the latitude?

6. —— Sirius (α of Canis Major) culminating, α of Virgo (Spica) rising, what is the latitude.

7. On the 18th of September, the sun appears at a point in the heavens which is scarcely one degree south of β of Virgo: in what latitude will Aldebaran set at noon on that day?

8. On the 28th May, Aldebaran comes to the meridian with the sun. It happened to be full moon exactly at noon of this day at Bath: what was the latitude in which Regulus (in the Lion's heart) was rising at that instant, and how was the moon situated where Regulus was setting instead of rising? (See question 9 of Prob. XI.)

PROBLEM XIV.

TERRESTRIAL GLOBE.

To find a place having its Latitude and Longitude given.

Conversely.—Having a place given to find its Latitude and Longitude.

Repeat the following:—

Right Sphere, (def. 49); Parallel Sphere, (def. 50); Oblique Sphere, (def. 51); Oblique Ascension, (def. 54); Oblique Descension, (def. 55).

Rule.—Follow the directions respecting the arrangements of the Globe, and the proper use of the right or left hand, in Problem II. Place the thumb nail upon the given latitude, and bring the given longitude to the brass meridian; then under the given latitude will be the place required.

Conversely.—If a given place be brought (with the right or left hand according to its north or south position) to coincide with the brass meridian, the latitude will be found over the place; and the longitude, or inclination of the plane of its meridian to the east or west of that of London, will be cut by the brass meridian on the Equator.

Find the places answering to the following latitudes and longitudes:—

32½ N.	17 W.	39½ N.	2½ E.
13 N.	80½ E.	56 N.	3¼ W.
34½ S.	18½ E.	51½ N.	0 E. or W.
15¾ S.	5¾ W.	5 S.	119¾ E.
50 N.	5¾ W.	34½ S.	58½ W.

Find the latitudes and longitudes answering to the following places:—

1. Moscow.
2. Bermuda.
3. Port Jackson.
4. Barbadoes.
5. Archangel.
6. Dublin.
7. Owhyhee, (S. point of)
8. Jeddo.
9. Oporto.
10. Otaheite.
11. Calcutta.
12. Lima.
13. Quito.

PROBLEM XV.

CELESTIAL GLOBE.

Having a given Star, to find what other Stars lie in the same plane with that Star and the two poles of the Equinoctial, and consequently with the whole axis of our earth.

Repeat the following:—

Equinoctial, (def. 14); Examine, by the Globe, the List of Constellations, (pages 55—58). Repeat again, Greek Alphabet, (p. 24.)

RULE.—Make the poles of the Equinoctial coincide with the wooden circle of the globe, and bring the given star to the graduated surface of the brass meridian; then all stars coinciding with the brass meridian will be the stars required.

Note.—The stars coinciding with the under semi-circle of the brass meridian are also in the same plane; but may, in this instance, be left unnoticed.

1. What remarkable star in Ursa Minor; what stars in Cassiopeia, Pegasus, the Phœnix, and Hydrus, are nearly in the same plane with α of Andromeda and the Polar points; and, consequently, in the same plane with our whole axis?

By bringing α of Andromeda, which I find to be in the head of that Constellation, to coincide with the graduated edge of the brass meridian, I see that the Pole Star, (which is not at the Pole), is then just 1½° above it; and that β in the chair of Cassiopeia, γ (Algenib) in the wing of Pegasus, ε in the wing of the Phœnix, and β in Hydrus, are likewise on the meridian.

2. What stars in Andromeda, Triangulum, Pisces, Cetus,* Eridanus, and Hydrus, are in the same meridional plane at any instant, with α in the Head of Aries?

3. What stars in Perseus, Sceptrum, Eridanus, and Dorados, are in the same plane with Aldebaran; and *how is that plane numbered where it cuts the Equinoctial?*

4. What stars in Auriga, Lepus, and Columba, are brought to any meridian at the same time with Betelgeux, (α of Orion): and how is their common plane numbered on the Equinoctial?

5. What small stars in the Lynx, Gemini, Monoceros, and Argo Navis culminate at the same instant, (or within two minutes of time, or a half degree), with α of Canis Major, (Sirius)?

6. What stars in Ursa Major, Leo Minor, Leo Major, and

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* If the globe should not have the smaller stars marked with sufficient clearness, the exact *part* of the Constellation may be named.

Argo Navis, are on my meridian, at the same time every day, with α of Hydra, (Cor Hydræ); and how is the plane passing through them marked on the equinoctial?

7. When the Southern "Pointers," α and γ of Crux, are on the meridian of any place, what stars in Musca Australis, Corvus, Coma Bernices, and Draco are culminating; and what point of the equinoctial is culminating with them all?

8. When η of Boötes is on the meridian, what star in the Great Bear's Tail, what little star in Virgo, and what considerable star in Centaurus, are likewise very nearly on the meridian?

9. What stars in Ursa Minor, in Draco, in Corona Borealis, in Serpens, in Lupus, and in Triangulum Australe, are on the meridian with γ of Libra; and what point of the equinoctial culminates with them?

10. What three stars in Hercules, what stars in Serpentarius, and what two remarkable stars in Ara, culminate every day about 5 minutes before ζ of Draco?*

11. What stars in Draco, Cygnus, Sagittarius, and Pavo, come to the meridian with α of Aquila (Altair); and what degree of the equinoctial?

12. What degree of the equinoctial, and what small stars in Cepheus, Pegasus, Aquarius, and Grus, culminate every day with α of Piscis Australis, (or "Fomalhaut")?

PROBLEM XVI.

TERRESTRIAL GLOBE.

To find a star, or any heavenly body, having its Right Ascension and Declination given.

Conversely.—Having a star, &c., given, to find its R. A. and Declination.

Repeat the following:—

Sidereal Clock, (def. 53); Magnitude of a Star, (def. 5); Aberration, (def. 103); Nebula, (def. 106); Galaxy, (def. 107.)

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* Near the pole of the Ecliptic, and just *preceding* it; *i, e.* westward of it.

Rule.—Place the poles in the horizon, so that, in causing the globe to revolve westward, all the stars mapped upon it may pass under review. Place the thumb nail (of the right or left hand according to position) on the given declination, and bring the given right ascension to the brass meridian; then, under the given declination will be the star required.

Conversely.—If a given star be brought to the brass meridian, the declination will be that found exactly over the star; and the R. A. will be cut by the brass meridian on the equinoctial.

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1. Find the stars answering to the following R. A. and Declination?

	h.	m.		Decl.		h.	m.		Decl.
R. A.	20	35	....	44¾ N.	R. A.	1	58	....	22¾ N.
,,	10	0	....	12¾ N.	,,	46½°		....	9½ S.
,,	22	48	....	30½ S.	,,	83°		....	34¼ S.
,,	12	17	....	62¼ S.	,,	11¼°		....	59½ N.

2. Find the R. A. and Declination of the following stars?

1st. The R. A. in hours or sidereal time.	2nd. The R. A. in degrees.
(β of Orion) "Rigel."	α of Crux.
γ of Leo Major.	β of Corvus.
α of Corona Borealis.	ξ of Ursa Major, "Mizar."
δ of Cancer.	α of Ursa Minor, Pole Star.
κ of Scorpio, (in the Tail.)	γ of Grus.

3. The telescope of my Transit instrument is elevated to 23° 26′ N. declination, and my sidereal clock is showing 3 hours 31 minutes: what star shall I see at the intersection of the wires which point out the centre of the tube, if I look through it just six minutes and three quarters after this?

PROBLEM XVII.

TERRESTRIAL GLOBE.

To find the difference of Longitude of any two places; and the hour of the day at the one place being given, to find the hour at the other place.

Learn S. T. V. W. on page 12, and X. on page 13.

Rule.—Find the longitudes of both places, beginning with that place which is eastern of the two. If the longitudes be both of the eastern hemisphere, or both of the western, subtract the less longitude from the greater; but, if the one longitude be of the eastern, and the other of the western hemisphere, their *sum* will be the difference of longitude, unless it exceed 180 degrees.

If the sum of the two longitudes exceed 180°, take that sum from 360°, and the remainder will show the difference of longitude.

N. B. The difference of longitude may be turned into minutes of time by multiplying the degrees by 4; or into hours by dividing them by 15.

What is the difference of longitude between the following places: Pekin and Lisbon; Botany Bay and Cairo; Port Royal and Owhyhee; Naples and Lassa, (Thibet); Geneva and Lima; Philadelphia and Venice; Paris and Rome; Lisbon and Canton; Astracan and Barbadoes; Mexico and Otaheite; the North Foreland and the Isle of Wight; Dublin and Edinburgh; what is the difference of time between these places, and which one, of every two of them, has the time in advance?

graphical miles in a degree of longitude, since each degree answers to 4 minutes of time, the rate per minute, multiplied by 4, will give those Geographical miles.

If the meridians be drawn, (as they are on some Globes,) through every 10 degrees, the rate in Geographical miles is similarly found for every two-thirds of a minute only: in this case the rate per minute will be half as much again as that shown by the measurement.

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1. At what rate per minute are the inhabitants of Petersburgh carried by the rotation of the earth?

Here I find, that the 15° of Petersburgh answer to 7½° only of the Equatorial degrees, and that, consequently, its inhabitants are carried only 7½ Geographical miles per minute.

2. At what rate per minute, (in Geographical miles,) are the inhabitants of the following places carried by the revolution of the earth upon its axis:—1. Madrid, or Pekin, or Philadelphia. 2. North point of St. Domingo, or north of Owhyhee. 3. Port Jackson, or Cape Town. 4. Edinburgh, or Cape Horn. 5. London. 6. Bermuda. 7. Canton. 8. St. Helena. 9. Cape Verd. 10. S. of Spitzbergen.

3. What also is the rate per hour at each of these places, and what the length of a degree in English miles?

Note.—The learner, in performing the foregoing Problem, will have noticed that the quadrant, (the measure of a *great* circle,) does not conform sufficiently to any arc of a parallel of latitude, (a *small* circle,) to enable us to obtain more than an approximation to the truth. If it be required to know the rate in English miles, they may be found, in this case with sufficient exactness, by multiplying the Geographical miles by 70, and dividing by 60; or by adding ⅙.

PROBLEM XIX.

TERRESTRIAL GLOBE.

The hour of the day at any particular place being given, to find the hour in any other part of the world, and where it is any other proposed hour.

Learn the Trigonometrical Canon given in K, on p. 16, and on the page succeeding.

Rule 1.—Bring the place, the time of which is given, to the brass meridian, and set the index of the hour circle to the time; then bring the other place to the brass meridian, and the index will point out the time required.

2. If it be required to find where it is any other proposed time; by turning the Globe until the index points to that proposed time, the places having that time will be found coinciding with the brass meridian; but due regard must be paid to the note appended to Rule of Prob. XII.

No 1.

Places at which Time is given.		*Places at which Time is required.*
London	10¼ A. M. ..	Washington and Owhyhee.
Jamaica(Pt.Royal)	9 A. M. ..	Madras and Bencoolen.
Calcutta	7¼ P. M. ..	Cayenne.
Edinburgh	3 P. M. ..	Delhi.
Venice	2½ A. M. ..	New York.
Cape of Good Hope	Midnt. ..	Pekin and Buenos Ayres.

No. 2.

New Zealand, (N. Cape.)	1 A. M. ..	Where Noon.
Ispahan	2¾ P. M. ..	Where Noon and where 8h. 20m. A. M.
Bombay	Noon. ..	Where 6½ A. M.
St. Helena ..	6h. 40m. A.M. ..	Where 1 P. M.
Mexico	Midnt. ..	Where 5 A. M. and where 2¼ P. M.

EQUINOCTIAL AND ECLIPTIC.

B The pleasantness of the pupil's progress will much depend upon his just comprehension of the *Equinoctial* and *Ecliptic.* We hope he has already obtained correct ideas of a *Plane :* by means of this portion of his knowledge the ecliptic and equinoctial may easily be understood by him.

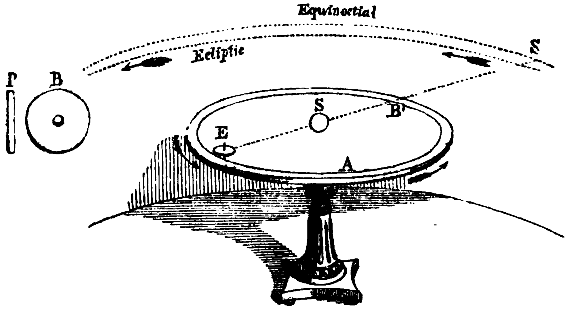
We set out (page 3) by illustrating the point called the *centre,* within the needle-hole; and explained that the circumference of this minute circle, and the surface of the paper in which it had been pierced, the surface of the table on which the paper was laid, and the surfaces of the distant tables in any rooms, on the same floor, which were exactly of the same height, were *in the same plane* with this circle and its invisible centre.

C Now, the earth, the surface of which we, and one thousand millions of our species, inhabit, is but a speck compared with the space in which it is situated ; yet it has a centre, and we can very readily understand, that this centre, being the middle of its axis, is in the same plane with the equator; (see def. 13,) and that, as the earth is surrounded by stars, being situated in the midst of myriads of them, there must be a circle of these stars, or of points of space amongst them, exactly *opposite* to the several points all around this equator ; that is, there is *a circular line* amongst the stars *in the same plane with our equator and its centre :*—that line is the *equinoctial.* We see it is only an imaginary line, drawn over the several points in the sky which are exactly opposite our equator. A man living at the equator, as the earth turns on its axis every 23 hours, 56 minutes, 4 seconds, will therefore direct his head to every part of this equinoctial line.

D But, whilst the earth is turning thus on its axis 366 times, it is wheeling round the sun, its primary, in a nearly circular path; which, although vast compared with the earth's own dimensions, is proved to be insignificantly little when contrasted with the distance of the nearest fixed star: (G on page 4). So that, we may say any one part of this circular path, or orbit, of the earth, is as distant from any fixed stars as other part of it, both being at an incalculable distance from them. Still, as with regard to the equator and the marking out of its plane in the heavens, called the equinoctial, so with regard to this circular path or orbit of the earth around the sun; there are stars, and points of space amongst them, *in the same plane with this circular path*; and these, being traced out amongst the stars, form the line called *the ecliptic*, which, like the equinoctial, is marked out on our celestial globe.

F The sun, around which we are thus circling, must, of course, be in the same plane with every point of this our path; and looking across the circle towards him, we should, were it not for his brilliant light, day after day perceive the stars so in the plane of our orbit, appearing, in consequence of our own motion in this orbit, to pass *behind* him in *the opposite way* to that in which we are going; in other words, forgetting the fact of our own movement, it would appear as if he were *passing over them in the same way*. This is the sun's motion in the ecliptic; not a real motion, but a seeming one, caused by our daily progress around him. If we were inhabitants of the sun to day, and had eyes, as now, capable of viewing so small a speck as the earth at so great a distance, we should see our planetary habitation also in the ecliptic line, but in the opposite portion of it; that is, as a bright speck appearing amongst those zodiacal stars which will be on our meridian this midnight, and making *real* progress in the same order as this *apparent* progress of the sun.

OBLIQUITY OF THE ECLIPTIC—EQUINOCTIAL POINTS—RIGHT ASCENSION—DECLINATION.



G We shall still have recourse to very homely expedients, in the use of a round tea-table, and the earliest home-made toy of our infancy,—a teetotum formed of a mould button and a wooden peg. Only, since our purpose is *now* a philosophical one, we will take care that our wooden peg (P) be exactly equal to the diameter of our horn button (B); and that the button be so placed on the peg as to be at equal distances from its two ends.

The peg, so placed, will now be the earth's *axis*.

Its ends, the north and south *poles*.

The round flat button will be a fit representation of *the plane of the equator*. (The young reader will allow, that if the space above and below this equatorial plane were filled with cork, so as to make up the form of a globe, it would spin just as well; but we should not then *see* the position of the plane of the equator.)

The surface of our table is *the plane of the ecliptic;* and, if we suppose a groove or track to be made near its edge, it will represent the earth's *orbit*.

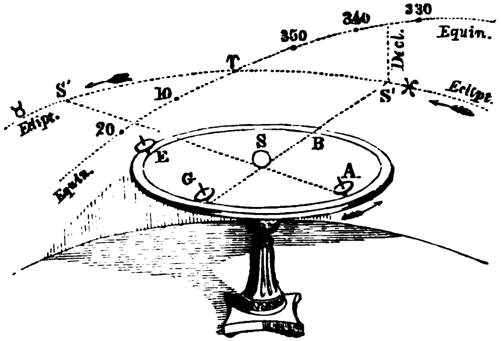
The *sun* will be represented by the ball we have placed in the middle of the table.

Now, let our teetotum be spun towards the left, and turn round 366 times whilst it traverses the whole groove, passing A, in front of the pupil, towards B. If the peg or axis be *perpendicular* to the plane of its orbit, that is, if it spin in an upright position, as E in our figure above, the *two planes*, the button surface and the surface of the table, (the planes of the equator and of the orbit), *will be parallel;* and the portions of the distant wall, (supposed to be that of a large circular room), which we have marked as, severally, in *the same planes with the button and with the table*, will represent the equinoctial and the ecliptic; and, as they are so nearly together, being apart only to the extent of half the length of the peg, on a distant wall they would appear as one line.

H We remark then:—*If the earth were to revolve in its orbit, with its axis, or line about which it spins, perpendicular to the plane of that orbit, the equinoctial and ecliptic would be one and the same line on our celestial globe.*

But it is not so: the earth's axis is *inclined towards the plane of its orbit*, 23° 28′; and therefore, the plane of the equator is so inclined and intersects it.

If our teetotum could be made to spin, *leaning* exactly to this angle, of 23° 28′, it would more fitly represent the earth whilst moving around the sun.



[K] It will be observed, (fig. 2), that *just as the peg or axis is inclined*, the *button or plane of the equator is inclined*; and, of course, the line which would mark out on the wall, or amongst the stars, the several parts or points in the same plane with our equatorial button edge, will be inclined also, and to the same angle, viz., 23° 28′. Hence, we see that the equinoctial and ecliptic *intersect*, and form *distinct lines* in the sky. That point in the heavens *where* these imaginary lines so intersect, is the point from which astronomers reckon in assigning places to the several heavenly bodies. There is, of course, another intersection, diametrically opposite to this; that is, on the wall *behind* the pupil who examines our figure; and, in common language, we speak of these two intersections, viz., ♈ in front and ♎ behind us, together, as "the equinoxes."

[L] Before we quit the diagram to advance with our problems, we would call attention to the manner in which the constant daily change of "right ascension" and "declination" is effected. We have said that the first point of Aries (♈) is the reckoning point. It is evident that when the earth is in the position G, (see figure), the apparent *declination* of S is *south* of the equinoctial plane, and the right ascension about 335; and that it will then have advanced about 3° in the sign Pisces (♓). But let us follow it to A, and its inhabitants will then have the sun's R. A. about 18° only; its apparent place being about 20° in Aries (♈), and its position above the equinoctial, and in about 8° of *north declination*.

PROBLEMS.

SECTION II.

RELATING TO THE ANNUAL REVOLUTION OF THE EARTH.

PROBLEM I.

CELESTIAL GLOBE.

A day being given, to find the sun's longitude or place in the ecliptic and his consequent declination and right ascension.

Repeat the following:—

Ecliptic, (def. 61); Obliquity of the Ecliptic, (def. 62); Equinoctial Points, (def. 63); Geocentric, (def. 99); Heliocentric, (def. 100).

RULE.—Look for the given day in the circle of months on the wooden horizon; and against it, in the circle of signs, will be found "the sun's *place*" for that day. Look for the sign and degree corresponding to this in the ecliptic line; bring this degree to the brass meridian, and over it will be found the sun's north or south declination: the right ascension will be cut by the brazen meridian on the equinoctial.

Our memorial lines ("*On New-Year's-day, &c.*") in the Appendix, will give, with very little trouble, the sun's place for any day in the year, without reference to the wooden horizon, to any who may prefer such a mode of assistance.

Examples.—What is the sun's longitude, or "place in the ecliptic," for the following days; what his declination and right ascension; and what stars would appear very near him, if it were not for his beams, on the days we have marked thus* ?

March 13—*January 16 (a)—*Feb 10—Sept 19—*May 23—December 21—*December 1—*August 20—*October 14—June 21—*June 30—September 23—March 21—*November 5—April 25—*July 12 (b).

PROBLEM II.

TERRESTRIAL GLOBE.

A certain day of the year being given, to find what other day of the year is of a length exactly corresponding to it; and where, on those two days, the sun appears in the zenith.

Repeat the following :—

Solstitial Points, (def. 64) ; Tropics, (def. 65) ; Zones, (def. 71) ; Amphiscii, (def. 72) ; Ascii, (def. 73) ; Analemma, (def. 66).

Rule.—Find the sun's place and his declination, either on the celestial globe by the proper ecliptic line, or on the terrestrial globe by means of the record of declination answering to the ecliptic. Turn the globe till some other portion of this line is under the same degree of the brazen meridian; then find the sign and degree answering to it on the wooden circle of the globe, and directly against them will be the day of the month required.* The places having latitude answering to the declination of the sun, will be those to which he will, on these two days, pass vertically.

(a) 16th January, a little to the south-west of α and β, the remarkable stars in the Goat's head.

(b) 12th July, nearly half way between two very remarkable stars.

* If the analemma be used, the two dates will be found at once under the declination.

Examples.—Find the days corresponding in length to the following days; and the places to which, on those days, the sun is vertical.

1. 6th February—5th May—10th July—20th January—18th August.

Answer—4th November, &c. &c.

2. The sun rises to Greenwich at half-past four on the 29th of April; it will rise earlier next day: how many days must elapse before it will again rise precisely at this time?*

3. The sun sets to me in London, at three quarters past seven on the 2d of August; it will set earlier next day: how many days must elapse before he will again set precisely at that time?

4. If the sun be vertical at a certain place on the 15th of March, how many days must elapse before he is again vertical to that place, and to what other places will he then also be vertical?

Conversely. 5. Find the days on which the sun is within one degree of the zenith of Calcutta, or of the south point of California; and also how long he is daily within the same distance of the zenith of Quito, at each of two periods of the year.

PROBLEM III.

CELESTIAL GLOBE.

Given the day of the month and the sun's amplitude, to find the latitude of the place of observation.

Learn Zodiac, (def. 69); and the Memorial verses "On March 21st," &c., in the Appendix.

Rule.—Find the sun's place, and bringing it either eastward or westward of the brass meridian, elevate or depress the pole until that part of the ecliptic can be made to coincide with the given amplitude, as marked on the wooden circle of the globe; then the degrees of elevation of the pole, or the degree of declination in the zenith, will show the latitude.

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* Any two days which correspond in length, are equally distant from the 21st of June and the 21st of December, the longest and shortest days.

The sun, on any day, sets so many degrees north or south of the west, as he rises north or south of the east.

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1. In what latitude does the sun rise 25° north of the east, and set 25° north of west, on the 21st of June?

Here finding the first point of Cancer to be the sun's place, I elevate or depress the pole until that point of the ecliptic can be made to coincide with 25°, the given amplitude, and find that this can occur only in lat. 23° north or 23° south.

2. In how many different latitudes does the sun rise duly east and set duly west, on the 21st of March, and on the 23d of September?

3. What was the variation of the magnet, and in what direction from the *true* north, at a place where, on either of these two days, he appeared to be rising 24½° to the *south* of the east point of my compass, and to set 24½° to the north of its western point?

It will help the pupil to answer this question, if he consider whether the east point of the compass was too far north or too far south.

4. In what latitude north, and in what latitude south, does the sun rise north-east and set north-west on the 21st of June.

5. On what points of the compass does the sun of the 21st December rise and set in the latitudes last found?

6. In what latitude north on the 21st of June, did the sun rise with amplitude 80° north of east, having been *a very little time* below my horizon; and to the inhabitants of what latitude south, does the sun, on that day, rise with the same amplitude to give *a very short day*, having been *very many of the twenty-four hours* below their horizon?

7. In what latitudes (north and south) has the sun 22½° of amplitude on the 5th of May or on the 7th of August, on both of which days he has 16½° of north declination;

and what will be the difference of effect of his declination in these latitudes?

8. On the 3d of February, in what latitude north does the sun set 20° south of the true west; and whether does the north point of the magnet vary eastward or westward in a certain longitude on that parallel of latitude, if the sun, on that day, is found to be setting 30° south of the west of the compass?

ANNUAL DISTRIBUTION OF LIGHT AND HEAT.

The distribution of the light and heat* of the sun over the surface of our earth, is unequal and variable from several causes.

B *First.*—Its globular form, as its surface, in the higher latitudes, curves off and retires, receiving the sunbeams obliquely.

A board *twelve inches* square will entirely intercept the rays of light and heat which, at a corresponding distance from a lamp, exactly spread themselves over the more extensive half-surface of a *twelve inch* globe. The pupil can readily conceive over which portions of the globe-surface these rays are cast most thinly.

C *Secondly.* "The nature of the surface whether water or land; and the situation, whether at a greater or less height above the level of the ocean. To such circumstances may be added, the particular configuration and geographical relations of places; as their aspect to the north or south; their being sheltered or exposed; the composition and nature of the soil, particularly its colour and state of aggregation, on which depends its power* of absorbing and of radiating heat and light, and of retaining or of parting with humidity, &c.; the proximity, or absence of seas; the predominancy of certain winds; the frequency of clouds, fogs, &c."—*Prout's Bridgewater Treatise, p.* 216.

D *Thirdly.* The obliquity of the earth's axis of rotation to the plane in which it performs its annual revolution.

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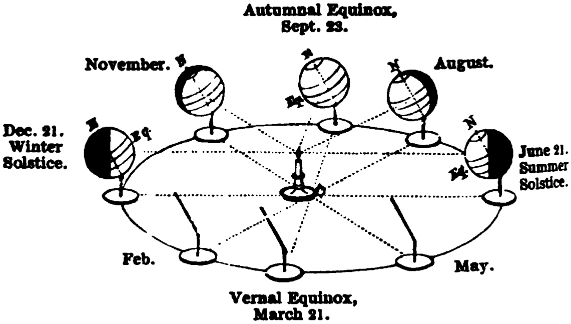
* See articles *Light* and *Heat* (Index).



The pupil is requested to observe, particularly, the latitude in which the vertical ray falls, as indicating the declination caused by the relative position of the axis.

We hope the explanation given on pages 106—8, have fully prepared the pupil for a just idea of the circumstances illustrated above. He will recollect that the axis (our button peg) maintains its parallelism during its 366 rotations, (otherwise our equinoctial plane would be a varying one); and he will now perceive that the consequence to our globular earth, is an ever-varying distribution of the sun's influence as it respects the latitudes of its surface: the sun (represented above by the taper) becoming, by this wondrous ordination of the Creator, a star of ever-changing declination; and, in the course of the year, or period of complete revolution, shedding its vertical rays in a range of latitude from 23° 28′ north, to 23° 28′ south of the equator. Hence the seasonal changes of summer, autumn, winter, and spring.

Our purpose will be answered by referring to the five positions particularly noted above: we begin with the position on the right, representing the extreme circumstances of the

21st OF JUNE, (*our* SUMMER SOLSTICE.)

F Here it may be seen that the northern extremity of the axis, or arctic pole, is *bowed towards the sun* to the exact extent of its inclination to the plane of the orbit. The taper flame, or sun, is therefore vertical in latitude 23° 28′ north; and affording, notwithstanding the earth's daily rotation, continuous light to the whole segment within the arctic circle; *i. e.*, to the whole of the north frigid zone, leaving a corresponding segment (the south frigid zone) continuously unenlightened.

Referring to Problem VI. of Section I., it will readily be understood that the equatorial inhabitants, as those of Quito or the north of Celebes, have an invariable period of twelve hours' light; but that of all the places which, at any instant, are rising into the sun's beams along the western edge of the terminator, those most southern will first arrive at its eastern edge to lose his light; whilst those most northern will enjoy it longest. And thus, since these are the extreme circumstances of our earth's position in sunlight, we have a representation of the longest day of the northern hemisphere, and the shortest day of the southern one.

AUGUST, (SECOND WEEK OF).

G We pass towards the left to view the condition of the earth in the early portion of August; and we remark that, in consequence of the curvature of its path, the *unvaried direction* of its axis is now, so to speak, considerably on one side of the sun; and the latitude now receiving his vertical beams about 15°. Hence his rays reach over the north pole to that extent only, and a considerable portion of the arctic or frigid zone is spending a part of the diurnal rotation of twenty-four hours out of their direct influence.

The equator still retaining its period of twelve hours, the summer days of the northern hemisphere are now considerably shortened, whilst the winter ones of the southern hemisphere are lengthening.

SEPTEMBER 23, (*our* AUTUMNAL EQUINOX).

H The earth has now attained a position with regard to the sun, at right angles* with that which it had at the solstices.

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* As may be seen in the cut, at the solstices there is a common plane passing through the axis, the polar point in the heavens, and the sun. This plane is represented on the celestial globe by the *solstitial colure*.

Its poles now are neither inclined towards the sun nor away from it: hence, its equator is receiving his vertical rays, and the terminator or boundary of his light, passing through the poles, coincides with the whole meridian of any place rising or setting, and divides every parallel of latitude into two equal parts. The sun now appears in the heavens without declination, coinciding, like γ of Virgo, or the star in the belt of Orion, with the equinoctial, and gives the name to that line, because when he is thus circumstanced, the nights and days of every latitude are of equal duration.

NOVEMBER, (FIRST WEEK OF).

K The circumstances of the southern hemisphere are now precisely those of the northern hemisphere in the position marked out for August. The north pole is inclined 15° from the sun; and that portion of the arctic zone which is not farther than 15° from the pole, or has above 75° of latitude, cannot rise into sun-light; a similar portion of the antarctic zone having it continuously. Hence, too, the sun is vertical in latitude 15° south; and appears in corresponding south declination. The inhabitants of the northern hemisphere have a shortness of day depending on their distance from the equator, whilst those of corresponding latitudes in the southern hemisphere, have corresponding shortness of night.

21st DECEMBER, (*our* WINTER SOLSTICE).

L The position of the earth on the day of the winter solstice, may be explained by referring to that of the 21st of June. It will be seen that the circumstances of the two hemispheres are now completely reversed. The arctic zone, the whole of which, on that occasion, had continuous light, is now entirely enveloped in darkness; whilst to the whole of the antarctic zone, the sun is constantly above the horizon. He is shedding his vertical rays in the latitude answering to the declination of the southern tropic, and the inhabitants of the southern hemisphere have now attained their longest day; the inhabitants of corresponding northern latitude having their night of corresponding length, and their day the shortest.

FEB. MAR. 21. MAY.

"The positions for these three occasions may be understood by reference to those which are opposite. It must be remarked, that whilst the consequences to the two hemispheres in February and May respectively, are the reverse of those in August and November, the circumstances of the 21st of March, as far as it respects the distribution of light, are precisely those of the 23d of September.

PROBLEM IV.

TERRESTRIAL GLOBE.

The day of the year being given, to find the length of that day in a certain latitude, and the altitude of the sun at any distant place, when he is setting at the place of observation.

Repeat the following :—

Heteroscii, (def. 74). Read and describe pp. 114—117.

Rule.—1. Find the sun's declination for the given day, and rectify the globe for that declination; the wooden circle of the globe will then represent the "terminator,"* or boundary of his direct beams; and the brass meridian, the plane in which the sun lies. Bring the given place to the brass meridian, and set the index to twelve, or noon. Turn the globe eastward, and count the hours passed over by the index until the place coincides with the eastern edge of the terminator; this will show the time from noon until sun-setting, or half the length of the day.

Subtract those hours from twelve or midnight, and it will show half the length of that night, or the time of sun-rising; since the sun rises so much after midnight as it sets

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[*] It represents the horizon, only of any place having latitude corresponding exactly to the declination of the sun, at the instant of noon.

before midnight; or so much before noon, as he sets after noon.

2. Keep the globe from rotating. Affix the quadrant of altitude to the sun's declination (*i. e.* to the latitude in which it is vertical); then, the graduated edge of the quadrant brought to coincide with any proposed place, will show its elevation in sun-light, or the altitude* at which the sun is appearing to its inhabitants at that instant.

N.B.—If the place should be found coinciding with the brass meridian, that circle may be used instead of the quadrant; and the degrees counted on it the shortest way towards the terminator, will show the meridian altitude of the sun at that place.

1. What is the length of the 15th of April or the 27th of August, to us in London; and how high is the sun above the western horizon of the island of Bermuda when it is setting here?

Elevating the north pole 10°, and bringing London to coincide with the brass meridian, we find that the index will have passed over 6 hrs. 53m., when London is coinciding with the eastern edge of the terminator, or is setting out of sun-light. Hence the time of sun-set being 6h. 53m., I subtract those hours from 12, or midnight, and I get—— for the time of sun-rise on these mornings, nearly. By affixing the quadrant, and passing its graduated edge over Bermuda, I find that that island has the pivot or sun 41° from its zenith, or is yet elevated ——degrees in his beams.

2. What is the length of the 25th of October at St. Helena; and how high has the sun risen above the eastern horizon of the east point of Owhyhee, when St. Helena is leaving sun-light?

3. When does the sun rise, and what, consequently, is the length of the night and of the day, at Clerke's Island

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* The pupil will understand this, if he considers that the number of degrees between the place and the terminator, is the *complement* of its distance from where the quadrant is screwed; viz., the zenith of the place to which the sun is vertical. If the places are situated nearly north or south of the sun, the brazen meridian will show the zenith distance and altitude.

(south of Behring's Straits) on the 10th of July; and when the sun is setting there on that day, what is his altitude at Mocha, where he is nearly north; at Calcutta, where he is declining westward; and at the Cape of Good Hope, where he appears advancing towards noon, considerably to the north of their east?

4. Find the time of sun-set at Petersburgh on the 21st of December; and the altitudes at which the sun appears at that instant to the inhabitants of the following places:—

To the south, at St. Helena, Gibraltar, Land's End, and the Faroe Islands.

To the north of the west of the Cape of Good Hope and Kerguelen's Land.

To the north of the east of Cape Horn.

To the south of the east of Antigua.

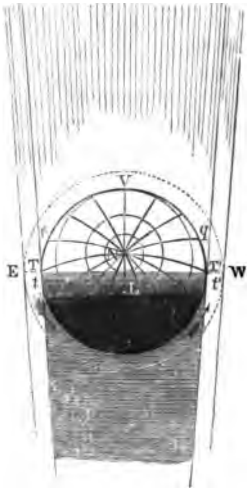
5. Find the time of sunset at Petersburgh on the 21st of June, its longest day, and describe the positions with regard to sun-light, of the above-named places at that instant.

PROBLEM V.

Remark.—We attended in Problem IV. Sect. I., and the succeeding, to the terrestrial globe as a model of our earth revolving on its axis in star-light; and found the "diurnal arcs" of several stars; that is, what portions of the time occupied by one rotation of the earth, were spent by places of given latitude in passing through the beams of a star of given declination.

We have since seen (page 108) how a constant change of the declination of the sun, the source of our day, is effected; and have proceeded to view some of the consequences of his change of declination in different latitudes. Referring also to the annexed figure, we remark that, owing to the power of his beams, the reflection of them upon "the vapours and minute solid particles which float in our atmosphere, and perhaps also, upon the actual material atoms of the air itself," is rendered so sensible to our eyes, as to be the means of conferring the important blessing of twilight, which continues until the sun has descended 18°; or, more correctly, (as the proper use of our terrestrial globe explains to us,) until, by the rotation of the earth, we have been carried 18° beyond the reach of those of his beams which fall *directly* upon its surface.

From the same cause we enjoy twilight for a corresponding portion of time before the sun rises; that is, before, by the rotation of the earth, that portion of its surface on which we dwell reaches his direct beams in the morning, or it is "sun-rise."



Let the annexed figure represent our earth with N, its north pole, elevated, say, 21 degrees above T T′, the terminator; then V will represent the spot at which the sun is vertical; and it is evident that, as the earth rotates in the direction shown by the arrows, a part of the surface will be deriving light from t′, an illuminated portion of the atmosphere, long before it can receive the direct beams of the sun by arriving at T′. In the same manner, after having lost them at T, the eastern edge of the terminator, it will continue to enjoy them for a similar length of time, as they are reflected by the similar portion of atmosphere, t.

TERRESTRIAL GLOBE.

The month, day, and hour at any place being given, to find that particular place on the earth where the sun is vertical, and all others that have noon; those places also which have morning twilight, and those to which the sun is rising; those places where the sun is setting; those which have evening twilight; and those places at which it is midnight.

Repeat the following:—

Disc, (def. 57); Eclipse, (def. 58); Eclipse of the Sun, (def. 59); Eclipse of the Moon, (def. 60). Read the preceding remark, and describe the figure.

RULE.—Elevate the pole to the declination of the sun: the wooden circle of the globe will then represent the "terminator" of his direct beams for the given day. Bring the place at which the time is given to the brass meridian, and set the index to 12. Give the globe its eastward rotation until the index have passed over so many hours as the given time is past the last noon.* And, lastly, affix the quadrant of altitude to the sun's declination. All places coinciding with the upper semicircle of the brazen meridian have noon; whilst those coinciding with its under semicircle have midnight. That particular place under the sun's declination has the sun vertical. The inhabitants of all places along the *western* edge of the terminator, see the sun in their eastern horizon, and are rising into his direct beams, having had the benefit of his twilight from the time of their being within 18° of this terminator. Those places along the eastern edge of the terminator have the sun setting in their west, as they are leaving his light; and all those places have evening twilight which are yet not more than 18° depressed below the terminator.

⁂ The degrees of depression below the terminator, are to be measured by the crepuscular graduation of the quadrant; and it will be well for the pupil to remark, that as each place is most depressed at *midnight*, there must be certain places, (differing according to their latitudes and the declination of the sun,) which are within the twilight limit at that hour, and therefore have *no real night*.

Examples.—Find where the sun is vertical, and where else it is noon; where it is morning twilight and where sun-rise; where it is sun-set, where evening twilight, and where midnight, at the several instants of time given at the following places:—

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[*] It is much better to disregard the very trifling difference of declination due, in some instances, to the next day, than to reverse the proper motion of the globe for the purpose of *bringing back* the time.

1. 17th of February or 23d of October. Lisbon ½ past 4 P.M.

Answer.—Vertical, Lima.—*Noon,* Port Royal, west part of Cuba, Cape "Look Out," Washington, Lake Ontario, Isle of Juan Fernandez, &c.—*Midnight,* Cambodia, Tonkin, Irkoutsk, &c., Bencoolen, (nearly).—*Rising,* Western of Sandwich Islands, Melville Island, Navigators' Isles, Friendly Isles, (nearly). — *Morning Twilight,* Aleouskie Islands, the Fejees, New Zealand. &c.—*Setting,* North of Iceland, North of Ireland, South-west of England, Iviza, Loango, Cape of Good Hope, (nearly).—*Evening Twilight,* Norway, Germany, Italy, Greece, Coast of Natal, &c.

2. 19th of May or 24th of July. London, 24m. past 10 P.M.

3. 21st of June, (*our* longest day, or "summer solstice"). Greenwich, 28m. past 4 A.M.

4. 21st of March or 23d of September, ("the Equinoxes.") St. Helena, or Gibraltar, or Land's End, 5 P.M.

5. On 21st of March or 23d of September, when midnight at London, or Havre, or Valencia, note a particular island which is about to have twilight at midnight.

6. 21st of December, (*our* shortest day, or "winter solstice.") Bombay, 20m. to 7 A.M.: where is the sun vertical, where rising, &c.

7. 2d of June or 10th of July. Blackheath, midnight, where is the sun rising, where setting, &c., and note particularly, where twilight at midnight.

8. Suppose that in a certain year, on the 5th of January, at the time when the sun is vertical at Osnaburgh Island, (south-east of Otaheite,) the full moon be *exactly* opposite to the sun, and therefore *totally* eclipsed by the shadow of our earth; at what remarkable place in Arabia is the moon* vertically thus eclipsed; what places, as the earth revolves, are leaving the sun-beams to behold her in this condition; and at what places can the inhabitants, at that instant looking northward, point with the right hand to the sun rising in their eastern horizon, and with the left to the moon, setting thus eclipsed near their west?†

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* The moon, at the time of total eclipse, is not invisible, but appears of a tarnished copper colour.

† In consequence of the refracting power of the atmosphere, the sun and moon may, in this case, be both of them just *above* the horizon.

PROBLEM VI.

TERRESTRIAL GLOBE.

The day of the year being given, to note all places to which the sun on that day does not set, and those places where the sun does not rise; and to record his elevations at noon and midnight in the longitudes of the former places; and his depressions below the horizon at noon and midnight, in the longitudes of the latter.

Learn Polar Circles, (def. 68); Periscii, (def. 75).

Rule.—Rectify the globe for the north or south declination of the sun: then, as will be seen, all places not more degrees from the enlightened pole than are equal to the sun's declination, or (which is the same thing) all places having latitude in the summer hemisphere greater than the complement of his declination, cannot lose his beams; whilst those having corresponding latitude in the other hemisphere, cannot receive them.

2. Bring the given place, whether elevated or depressed, to that semicircle of the brass meridian which is graduated from the equator towards the poles; and reckon the number of degrees, the shorter way, between the place and the upper surface of the wooden circle, or " terminator:" this will give the elevation or depression of the sun at that place at the *mid-day* of its longitude.

3. Bring the given place to that semicircle of the brass meridian which is graduated from the poles towards the equator; and the number of degrees reckoned, as before, between the place and the terminator, will give the elevation or depression of the sun at the *midnight* of the longitude of that place.

⁂ The pupil will still bear in mind, that every place less than 18° depressed, has twilight.

1. Find what places are having continuous sun-light at midnight of the 28th of May; and, of these find, at each

of the undermentioned places, the elevation of the sun at mid-day, when their inhabitants see the sun southward; and his elevation at midnight, when they look at him across the north pole, and see him northward:—

North Cape of Lapland; north point of Nova Zembla; north point of Spitzbergen; south point of Nova Zembla?

North Cape Lapland, *noon* 41°; *midnight* 3°. North point of Nova Zembla, *noon* 35½°; *midnight* 8½°, &c., &c., &c.

2. Find what are the depressions or elevations of the sun at these places on the 5th of November; both when it is noon, and when it is midnight, at all places corresponding with them, severally, in longitude, and therefore in time?

3. On the 20th of February, 1823, Captain Weddell reached 74½° of south latitude.* Find the altitude of the sun on this occasion, at noon, when his crew looked northward at the sun; and its depression at midnight, when they looked across the south pole towards that luminary, and, consequently, saw its light strongly reflected upon the clouds near the south point of their horizon?

4. What would have been the elevation and depression of the sun at noon and at midnight, to his crew, had they remained in that latitude until the equinox (March 21st); and would they have had any *real* night during the twenty-four hours of that day?

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5. Find how much London is depressed below the terminator at midnight of the 21st of March, or of the 23d of September; and how far the sun must shine over the north pole (*i. e.*, how much the north pole must be inclined towards the sun,) in order that London may be within the twilight limit at that hour?

6. What must be the north declination of the sun, that is, how far must the north pole of our earth *incline* into his beams, in order that the following places may have no real night during a portion of the summer:—Paris, Madrid, Rome, Edinburgh:—and at which of them cannot that circumstance occur?

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* *Any* longitude in the given latitude may be taken.

PROBLEM VII.

TERRESTRIAL GLOBE.

Given the longitude and the sun's meridian altitude on a certain day, to find the place where the observation was made.

Read and explain, H, given with the diagram on page 19. Read page 49 in explanation of page 48.

Rule.—Since there are always 90° between the horizon and the zenith, the complement of the altitude of any heavenly body, or what it wants of 90°, is equal to the zenith distance; hence,—

Find the sun's declination. Subtract the meridian altitude from 90°, and it will show the meridian zenith distance. Bring the given longitude to the brass meridian; then, if the sun was south, and the place consequently north of where it was vertical, count the degrees of this zenith distance northward from the sun's declination, and it will show the zenith of the required place. If the sun was north of the place of observation, count southward of the sun's declination in like manner.

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1. 20th May, 1839, longitude 64½ W. Sun's meridian altitude 77½° and south of the place: where was I?

2. At sea, 3d March, in longitude 5¾° W. I observed the sun when on the meridian and north of my zenith, to have an altitude of 81°: where was the ship?

Find the places at which the following observations were made on the days prefixed:—

3. 6th July; Greenwich chronometer showing 20m. past 9 in the morning; sun on the meridian and south, at 48½° altitude.

4. 18th Sept.; London time, as shown by my watch, being 8m. past 5, P. M.; sun on the meridian, and south of me; altitude 74°.

5. 15th Oct.; 13m. past 11, P. M. I observe an immersion of Jupiter's 1st satellite; time given for this in the Ephemeris, (London,) 10 o'clock, P. M.; altitude of sun last noon 64½°, and north.

6. On the 27th May, 1840, at Greenwich; (but on 26th May where I was;) I observed an immersion of Jupiter's second satellite; exact time at the place 50m. past 11, and latitude, as determined by the stars that evening, and by the sun at the last noon, 20½° S. Refer to page 34 of White's Ephemeris, given on our pages 52 and 53, and determine my station?

PROBLEM VIII.

CELESTIAL GLOBE.

Having a given day, to find at what time a certain star comes to the meridian.

Learn Aspect, (def. 89); Read page 50 in explanation of page 51. Explain the "Speculum Phænomenorum," on page 52, by attention to page 53.

RULE.—Find the sun's right ascension, and note whether the star (above the horizon or below it) be situated E. or W. of the plane of the meridian, when the sun is coinciding with it. Find the right ascension of the star, and subtract the less R. A. from the greater: then, if the remainder be less than 180°, when turned into time it will show how much earlier or later than noon the given star culminates. If the remainder be greater than 180°, subtract it from 360°, and what then remains, when turned into time, is the distance from noon. If the star be west of the sun it will have culminated before noon; if to the east of the sun, it will culminate after noon.

If the R. A. be given, as it frequently is, in time, subtract the hours and minutes of the one, from the hours and minutes of the other: then, if the remainder be less than 12 hours, it is the difference of earlier or later culminating: If the remainder be greater than 12 hours, subtract it from 24 hours, and what then remains is the difference of R. A., or of the time of culminating.

The Problem may be performed mechanically by means of the sun's place and the index, as in the next Problem; but the questions are so put as to elicit the *difference* of Right Ascension, and impress the cause of the daily alteration of that difference.

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1. There are three stars α, β, γ, of the 2nd. magnitude, in the constellation Andromeda: find the difference of their Right Ascension and that of the sun, on 21st March, and on the 4th April, (just a fortnight after); and the precise times of each of these stars coming to the meridian on these two days?

2. On 6th July, 1840, the planets had very nearly the following R. A.:—

☿ Mercury....	8h. 44m.	Find, very nearly, their times of culminating on that day.
♀ Venus.....	6h. 48m.	
♂ Mars......	7h. 24m.	
♃ Jupiter	14h. 28m.	
♄ Saturn.....	17h. 4m.	
♅ Uranus	23h. 26m.	

3. On the 10th March, at what time does Sirius, (*a* of Canis Major,) come to the meridian?

4. On the same day when do Altair, (*a* of Aquila,) and Regulus, (*a* of Leo Major,) culminate?

5. Find at what time Betelgeux, and Castor, and Vega, culminate at any place on the 22d of December?

PROBLEM IX.

CELESTIAL GLOBE.

The day, and hour, and the latitude of the place being given, to find what stars are rising, culminating, and setting; and so to arrange the axis of the globe, as that the stars depicted on its surface may, each of them, be exactly opposite their corresponding stars in the heavens.

Repeat the following:—

Astronomical and Civil Reckoning, (def. 82); Sidereal day, (def. 83); Solar day, (def. 84); Compass, (def. 36); Variation of the Compass, (def. 37).

Rule 1.—Elevate the pole to the latitude of the place; this will bring the proper declination to the zenith, and cause the wooden circle to represent the horizon.

2. If the noon of the given day have passed, find the sun's place for *that* day: if the noon of the given day have not yet passed, find the sun's place for the *preceding* day.

3. Bring the sun's place so found to the meridian; set the hour-circle to 12, and turn the globe, (westward,) so many hours* as the given time is past the last noon. Then

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* It is of great importance to learners of the use of the Globes, whose study, in many instances, ought to be a constant correction of erroneous impressions respecting appearances and realities, to be guarded against moving either of the Globes in the wrong direction; excepting so far as may be necessary when making a mere search on the surface (as in Prob. I., IX., &c. of Sect. 1st.) Our method of reckoning from the *last* noon, and giving the celestial globe (a model of the sphere of stars) its own *westward* apparent motion, will, we are convinced, be found to prevent perplexity. The same remark applies to the *eastward* rotation of our earth, and the representation of this real motion by the terrestrial globe.

the stars appearing on the eastern semicircle of the horizon, are those which are rising; those coinciding with the graduated edge of the brass meridian are culminating; and those on the western semicircle of the horizon are setting, at the time proposed.

N. B. If the question (as No. 11) relate to the place and time at which the Problem is performed, make the brass meridian coincide with the plane of the meridian of the place by the compass, (as directed in def. 37.) Then, the problem having been performed, if the flat end of a pencil be placed upon any star, its point will be exactly directed to the corresponding star in the heavens.*

1. What stars, or parts of constellations, are rising, culminating, and setting, at Petersburgh, on 16th January, at ¼ to 7. P. M.?

2. What stars, or parts of constellations, are rising, culminating, and setting, at Petersburgh, at the same time of evening, on 26th January, (10 days after the preceding date)?

Find the stars, or parts of constellations, rising, culminating, and setting, to the inhabitants of the following places, at the following times at those places:—

3. London, or Reading, or Bristol, 21 Dec. at ½ past 1, A. M.

4. Cape Horn, 16th August, ¾ past 2, A. M.

5. Jamaica, (North point,) 17 November, 11, P. M.

6. Otaheite, 17 Nov. 11, P. M.

7. Quito, 3 Sept. ¼ past 8, A. M.

8. Quito, 3 Sep. ¾ past 2, P. M.

9. The following places are on the same meridians, and therefore have corresponding clocks: find what stars are rising and setting at each of them on 8th August, at ½ past 10, P. M. to show the consequence of a change of latitude: and note, particularly, the effect on the rising of

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* The stars are all a little out of place by refraction; but those near the horizon, and most affected by it, are not so affected as to appear displaced in this case.

a of Pisces—St. Helena, latitude 16° S.; Land's End, latitude 50 N.?

10. What stars, or parts of constellations, rise, culminate, and set, to the inhabitants of Madrid, or Philadelphia, or Pekin, at the several instants when it is three o'clock in the morning to these places, on the 15th May?

11. Point to the several principal stars of the constellations displayed in our hemisphere at Blackheath, at ½ past 8 o'clock, of the following evenings: 27th April, 1st June, 22d August, 30th October, 1st December, and record those that are rising at that time?

12. Let the pupil be imagined to be in the same latitude, viz. 51½ N.; but just south of Queen Charlotte's Island, and the time *there* to be ½ past 8 o'clock: then, being situated westward of the magnetic pole, (see *Magnetism*) and the variation, consequently, being East, (say about 12°,) let the same stars be pointed to.

PHÆNOMENA OF THE FRIGID ZONES.

Remark.—We have seen (Prob. III. p. 112) that the greater the declination of the sun, the greater his northern or southern amplitude in any latitude; the effect being to lengthen the day or to lengthen the night, according as the declination has, or has not, the same name with the latitude.

We have seen, also, (Prob. VI. p. 124,) that the inhabitants of certain latitudes cannot lose the sun-light during the days on which the sun has greater declination in their hemisphere than is equal to their distance from the pole, or their co-latitude; and that when his declination is such in the opposite hemisphere, they cannot receive his rays.

In the north frigid zone, from the 21st of March, (when, as in lower latitudes, he rises duly east to set duly west, and give a twelve-hours' day,) the sun has been dividing the twenty-four hours unequally, making his daily visits more and more exceed the periods of his absence, by taking his departure in the evening of each succeeding day at a point of the horizon nearer to the north; and returning in the morning at a corresponding nearness to the north on the other side of the meridian. Thus, at last, the long period of sunlight arrives, when, so to speak, he makes his setting and his rising at the same instant, by *touching*, only, the north point of the horizon, after a twenty-four hours' circle above it; (like *a* of Lyra in the latitude of Greenwich). Each completion* of a revolution of twenty-four hours, now finds him over this northern point, (his lowest,) at a little increase of altitude, until the 21st of June; after which, each revolution, as gradually, finds him lower there, till he dips as before, day by day to dip and to emerge farther and farther from the north, and thus to lengthen his absence.

The 23d of September finds him again in the east and west, dispensing twelve hours of light, as on the 21st of March; but now, as he proceeds in southern declination, the day dwindles as his amplitude increases, until he makes his rising and his setting at once by *touching* only the *south* point of the horizon, to leave them, first to twilight and then to darkness (again to be relieved by twilight) for a period corresponding (nearly) to his lengthened visit at the opposite season of the year.

At length the southern portion of the horizon is again tinged with bright red, and becomes increasingly suffused with it at the noon of each revolution: then follow the noons of the appearance of increasing portions of his disk; and then again, his rising and setting, to give, first, a day of minutes, increasing, as he proceeds to rise and set farther and farther from the south through the equinoctial east and west, to the day of twenty-four hours, at the midnight of which, as before described, he *touches* the extreme *north* to remain above the horizon.

⁂ This will serve for a description of the circumstances of the antarctic, or *south* frigid zone, if we reverse the order of it by substituting the southern point of the horizon for the northern one; the 21st of December for the 21st of June; and the 23d of September for the 21st of March.

The learner will have observed, that the higher the latitude of the place, the more inclined to the horizon is the

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* *i. e.*, the *midnight* of the longitude.

apparent daily course of any heavenly body. In latitude 85°, for instance, the sun, which, at midnight of the 3d of April, touches the northern horizon, obtains an elevation of ten degrees only in proceeding from the north to the south during the succeeding twelve hours; such being his altitude when greatest, or at noon of that date. At the pole itself, where the inhabitants, if any, have a *parallel sphere,* (the equinoctial line describing their rational horizon,)* the place of the sun in the sphere, when he has not too great south declination, must, for weeks, be traceable, first by the point of strongest twilight, then by the point of most vivid redness, which will appear to traverse the whole horizon each twenty-four hours as the scenery rotates around the observer. When the sun's north *limb* (the upper portion of his circumference) first shows itself, (in consequence of refraction some days before the 21st of March,) it is gliding thus along: in the course of a few hours this floating segment of his disk visibly increases; then his centre appears; then his whole form: and thus he continues to ascend, in a course really spiral, but not perceptibly so, until, on the 21st of June, three months from his rising, he has attained his greatest altitude of 23° 28′ by attaining his greatest north declination; again to descend during three months, (21st of June to 23d of September,) by the same spiral course, to the equinoctial in the horizon.

PROBLEM X.

CELESTIAL GLOBE.

Having a latitude within the north Frigid Zone, to find the length of the period of the continual presence or absence of the sun; and to note some of the phenomena of the heavens during those periods.

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* At the poles, the distinction of east and west could not obtain, the whole horizon being to the south, and the polar point in the zenith.

Read over and explain the remarks on pp. 130—132.

Rule.—1. Elevate the pole to the latitude, and mark the two points in the ecliptic which are cut by the brazen meridian in the north point of the horizon: the day answering to that point of the ecliptic in which the sun is coming northward, is the day of the commencement of the long period of sun-light; and the interval between this day and the day answering to the other point, will give that period.

2. Note the two points of the ecliptic which are cut in like manner by the south point of the horizon, and the interval between the two corresponding days, reckoning from that on which the sun is going southward, will give the period of his long absence.

⁂ The quadrant of altitude fixed in the zenith, will measure altitudes and depressions as before. It must be remembered that the sun, whether above the horizon or below it, is always crossing the south of the meridian at noon, and the north of it at midnight.

Observe, the sun must be 18° depressed in order that stars of the sixth magnitude (and therefore the whole) may be seen at their rising or setting.

Stars of the 1st magnitude may appear at their rising or
setting when he is depressed .... 12°
of the 2d .... 13°
of the 3d .... 14° &c.

1. Messrs. Scoresby, in 1806, attained the latitude of 81½° N. On what days does the sun there begin and end his visit of longest continuance; and how long might Messrs. Scoresby have viewed the sun continually above the horizon, had their avocations permitted their stay in that latitude?

2. What are the different altitudes of the sun at the following hours of the following dates in latitude 82° 40′, attained by Captain Parry in his attempt to reach the pole across the ice during June and July, 1827?

Viz. 3d of June $\left\{\begin{array}{l}\text{At midnight,(a) at 4 A. M. and 10 A. M.}\\ \text{At noon, at 2 P. M. and 8 P. M.(b)}\end{array}\right.$
22d of August, at 6 A. M. and at 6 P. M.

The "fields" of ice are formed on the surface of the sea, and are the congelation of salt water. Icebergs which are the accumulated productions of centuries, and which sometimes attain the altitude of a thousand feet before they float, are formed near the cliffs of the shores, entirely from the fresh water, which proceeds in torrents from the meltings of the snow during the periods of the long presence of the sun. In the journey of Captain Parry, referred to above, he failed to reach the 83°. He found, on taking his observations, that the vast covering of the ocean over which he was travelling, was drifting daily faster southward than his party could traverse it towards the north.

3. In 1754, Mr. Stephens is said to have reached lat. 84½°. How long (without considering the effect of refraction) does the sun continue above the horizon in that latitude?

It is commonly during June that the vast shoals of ice formed from sea-water, are broken up: they are not dispersed and dissolved, (even where the locality admits of it,) until the end of that month. A dense fog then generally rests, for some weeks, on the sea-surface; the higher land alone being exposed to the sun-beams. When this fog disperses, the heat, which has been accumulating during so many weeks from the continuous though slanting rays of the sun, is so intense as to cause the pitch to run down the sides of vessels.

CAPTAIN PARRY'S FIRST VOYAGE, A.D., 1819.

Melville Island, lat. 74¾°, November 11. "Mr. Ross, having gone to the mast-head at noon, reported that he saw the sun. * * * On the following day we expected to see the sun again, and looked out from the mast-head for that purpose, but he did not re-appear." (page 115).

4. Refraction caused his appearance as described above, at noon of the 11th of November. How far (c) was the sun really depressed at noon on that day in that latitude?

(a) To avoid the stronger snow-glare, and to ensure the greater dryness of the ice, Captain Parry's party dined at midnight, travelling during five or six hours before and after that hour; and availing themselves of the greater portion of warmth, when the sun was higher, for resting and sleeping.

(b) At 2 P. M., the same as at 10 A. M., &c.

(c) The thickness of the wooden horizon will render it awkward to examine that portion of the ecliptic in which the sun is situated: to answer this question, therefore, find the sun's declination, and contrast it with the declination in the south point of the horizon or the co-latitude.

Nov. 17. "At noon to day we saw, for the first time at this hour, a star of the first magnitude (*Capella*); and, at half an hour past noon, those of the second magnitude in Ursa Major, were visible." (p. 116.)

5. What was the sun's depression at noon of Nov. 17?(*d*)

6. What were the azimuth and altitude of Capella, and of Arcturus; and why was Arcturus not then seen as well as Capella?(*e*)

February 3d. "At twenty minutes before apparent noon, the sun was seen from the Hecla's main-top, (fifty-one feet above the sea,) being the first time that this luminary had been visible to us since the 11th of November, a period of eighty-four days; or——days less than the time of its remaining actually beneath the horizon, independently of the effects of atmospherical refraction."—(p. 139.)

7. On what day would the sun have re-appeared(*f*) had there been no refraction; and on how many additional days have the inhabitants of that latitude the advantage of a portion of sun-light in consequence of this beautiful arrangement of Divine providence, which rendered the sun visible on the 3d of February? (*g*)

"A column of light had been observed by Captain Sabine, (on this day, 3d of February,) at 10 A. M., immediately over the spot where the sun was."—(p. 139.)

8. Give the depression of the sun at that time, and the point of the horizon in which this column of light appeared?

CAPTAIN PARRY'S SECOND VOYAGE, A.D., 1821.

Winter Island, where Captain Parry's ships were blocked up during the winter-months of 1821, is in lat. 66¼°, (not quite within the Arctic circle.) He had three hours daylight, for writing in the cabin, on the 21st of December.

Igloolik, lat. 69¼°, Dec. 2, 1822. "At apparent noon,——days after the sun had, independently of the effects of refraction, set to us for a period of more than——weeks, we caught a glimpse of its upper limb from the deck of the Fury."—(p. 383.)

(*d*) See note (*c*).

(*e*) Consider how it was that one of these stars was, at this hour, involved in strong twilight.

(*f*) *i. e.*, when, after his long absence, did he again attain declination corresponding to the co-latitude.

(*g*) The days of his appearance by refraction, *after* he has really ceased to rise, (viz., at the beginning of their long winter period,) are as many as those found here; hence we must *double* the number of days to answer the question.

Jan. 5, 1823. "The sky looked so red towards noon, that we were induced to look out for the sun from the mast-head, but without success, though we could not help fancying every moment, that it was about to burst above the horizon."

9. Find the length of the long period of the sun's absence at Igloolik, and also the days during which he is constantly above the horizon there.

CAPTAIN PARRY'S THIRD VOYAGE, 1824, 1825.

Port Bowen, lat. 73¼°. "As early as the 20th of November, Arcturus could very plainly be distinguished by the naked eye, when near the south meridian at noon."

10. Find the altitudes and azimuths of Spica Virginis, Regulus, Castor, and Capella, and of *α* of Lyra and Altair, at Port Bowen, at noon of the 20th of November; and, since Arcturus could be thus distinguished at noon, show why certain of these several stars might or might not also be discernible? (*h*)

11. The most remarkable of all the stars has declination very nearly corresponding to the co-latitude of Port Bowen; and, consequently, is visible in the south point of the horizon, when culminating in that latitude; at what hour does this take place on the 20th of November, and is the depression of the sun then such as to admit of this star's being seen? (*i*)

12. What declination must the sun have, in order that his twenty-four hours' course at Port Bowen, may be exactly similar to that of Aldebaran; and on what two days of the year does this occur?

13. What is the greatest depression of *β* Leonis at Port Bowen?

14. In what latitude is the course of Arcturus nearly similar to that of Aldebaran at Port Bowen; (*k*) and what is the length of the sun's long period in that latitude?

(*h*) One of these stars was too near the horizon and the twilight; others of them were more favourably situated than Arcturus.

(*i*) See the observation at the end of the rule.

(*k*) *i. e.*, in what latitude does the northern, or "lower culmination" of Arcturus, just touch the horizon?

15. On what day does the sun cease to give twilight to the North Pole, and on what day does twilight begin again? (*l*)

PROBLEM XI.

TERRESTRIAL GLOBE.

A number of days being given during which the sun is above the horizon or below it in the Frigid Zones, to find the latitude and the places.

Learn "climate" (def. 80.)

We have seen (particularly from Examples 1 and 9 of the last problem) that if a heavenly body have declination equal to the co-latitude of a place, it cannot rise, or cannot set there, according as the declination has, or has not, the same name with the latitude. The 21st June and the 21st December are the days of greatest declination of the sun; on these two days, therefore, either he is at his greatest elevation or at his lowest depression in the Frigid Zones; they are the middle days of the long period of light or of darkness. Hence—

For the long period of sun-light.

Rule.—Take half the number of days, and reckon them from the 21st of June: that declination of the sun which answers to the last day will give the co-latitude.

For the long period of the sun's absence.

Reckon half the number of days from the 21st of December, and the declination of the sun answering to the last day will give the co-latitude.

The latitude may be found by subtracting the co-latitude from 90°; or the places may be seen as they pass

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(*l*) It must be remembered, that the equinoctial coincides with the horizon of the north pole, and that, consequently, the sun's depression at any date of the winter period, is equal to his declination.

below the pole, the under semi-circle of the brass meridian being graduated for co-latitude.

⁂ If these periods be required for the South Frigid Zone, for 21st June read 21st December.

1. In what part of the North Frigid Zone have the inhabitants, if there be any, constant sun-light for 158 days?

Here, (half the number of days being 79,) the 9 days remaining in June, the 31 of July, the 31 of August and the first 8 of September will make up the half period, and point out the declination of the sun, when he sets, to be 5½° north; hence the latitude must be 84½°.

2. In what part of the North Frigid Zone are the inhabitants, if there be any, deprived of sun-light for 149 days? *

3. In what part of the South Frigid Zone would the sun be absent during exactly 103 days, if the refraction of the atmosphere did not cause his disk to appear for some days above the horizon when he is really below it?

4. In what latitude of the South Frigid Zone would the sun be present exactly 97 days, if the same circumstance did not lengthen the period of his constant appearance?

5. In what latitude, north, is the sun above the horizon during 133 rotations of the earth about its axis? (*m*)

6. In what latitude, north, is the sun totally absent whilst the earth is turning on its axis 126 times?

7. Find the latitudes (and any places situated in them) which are the boundary latitudes of the *month climates*; *i. e.* those latitudes which have their long periods of sun-light *one*, *two*, *three*, *four*, and *five* months, reckoning 30 days to the month?

Conversely—8. By how many days does the period of the sun's constant presence at the north pole exceed that of his absence, whilst above the horizon of the south pole?

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* If the number of days given be uneven, the 21st December or the 21st June need not be included.

(*m*) The pupil is requested to note any remarkable coincidence that may present itself in answering these questions.

PROBLEM XII.

TERRESTRIAL GLOBE.

To find what places are situated in a given climate.

Conversely. To find the climate in which a given place is situated.

Repeat Zones, (def. 71); with the smaller print following *that definition.*

Since the *climates* of the Torrid and Temperate Zones are divisions in latitude depending on the *half-hours* of their longest day, and the sun sets so much after 12 as it rises before 12; the sun-set of the longest day in any one of these climates must differ exactly a *quarter* of an hour from that of the climate to the north or to the south of it. We have learned that the length of any given day depends entirely upon latitude: hence *any* meridian may serve to mark the boundaries of these climates, in the following manner;—

For the Northern Hour Climates.

Elevate the north pole 23½°, (the declination of the sun on the longest day); bring that portion of the first meridian* which cuts the equator, to the east of the terminator, and set the index to 6, (the invariable time of sun-set *there*.) Turn the globe such a portion of its rotation as is measured by the number of quarter-hours agreeing with the *number* of the climate; and that portion of the meridian which is then setting out of sun-light will be of the latitude which is the northern boundary of the climate required. Find its latitude by bringing it to the brass meridian, and the places may be seen as they pass underneath that latitude.

Conversely.—To find the climate in which a given place is situated. Having the pole elevated, as before, for the sun's greatest declination, bring the given place to the brazen meridian, and set the index to 12: give the globe its eastward rotation, and the number of *quarter-hours* past 6 at which the given place sets out of sun-light, will show the climate in which it is situated.

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* We take the first meridian as the most convenient; especially as, on some globes, the degrees of latitude are marked upon it.

The hour climates of the southern hemisphere may be found in a similar manner, the south pole being elevated for the 21st December; or, they may be inferred from the corresponding latitudes of the north.

⁂ If the several portions of a meridian thus differing by quarters of an hour in sun-setting, be marked by a dot of ink from a soft pen*, it will be seen that whilst the first of these geographical divisions contains nearly 8½°, they are so crowded in the high latitudes as to render it impossible to distinguish these with great accuracy on the globe; there are 8 climates between latitude 64° and latitude 66½°.

1. What places bound the 1st climate north of the Equator, and what bound the 2d?

2. What places are situated in the boundary of the 3rd climate?

3. What places are situated in the boundary of the 7th climate?

4. What places are situated in the boundary of the 9th climate?

5. What places are situated in the boundary of the 14th climate?

6. What places are situated in the boundaries of the 19th 20th and 24th climates?

Conversely.

7. In what climates are the following places situated? Malacca, Delhi, Havannah, Gibraltar, Jerusalem, Pekin, London, Edinburgh, Archangel, Mount Hecla, (Iceland.)

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* A small blot of ink may easily be wiped off from the varnished surface of the globe; a pencil will probably scratch it.

EQUATION OF TIME.

If our earth's axis were perpendicular to the plane of the annual orbit, (*i. e.* if our tee-totum button were spinning in an upright position,) it is shown in pages 106 and 107, that the lines, on the wall or in the sky, which represent the *positions* of the ecliptic and equinoctial planes, might be considered as one line; their separation being so little as to be insignificant, when considered with the distance of the wall, &c.

Now the earth's diurnal rotation, rudely represented by the spinning of our tee-totum, is the most equable of all known motions; astronomical science having records which prove that it has not deviated by any appreciable fraction of a moment during 2000 years. The *time* of the sidereal day which brings a star back to the exquisitely delicate cross wires of the transit instrument, is fulfilled each revolution to the hundreth portion of a second. It is then, evident, that if, whilst so rotating in an upright position, the earth's *orbitual* motion also were uniform, the sun (or ball) would appear to traverse the ecliptic (in this case the same with the equinoctial) in uniform daily portions; and each noon, or completion of the solar day, would bring *his* centre also into the exact centre of a telescope (so fixed as to be directed to his altitude) at the precise moment of time indicated by an exact clock, constructed (as our clocks are) to beat uniformly to such an interval.

Now, there are two circumstances which prevent this:—

First. The alternate acceleration and retardation of the earth's orbitual motion, as it gets nearer to the sun or goes farther from it in an elliptical course; and the consequent faster or slower apparent movement of the sun in the ecliptic.

And, *secondly*, the inclination of the earth's axis (our button peg) as shown on page 108; and the consequent obliquity of the equinoctial to the ecliptic.

The effect of the former of these two circumstances is not exhibited by the globe; except as we have found it in the fact, that the long winter periods of the North Frigid

Zone, are shorter than the long periods of sun-light; the sun spending fewer days in the southern portion of the zodiac. (Prob. XI., Examples 5 and 6). How far the obliquity of the ecliptic to the equinoctial interferes to produce a disagreement between the sun-dial and the clock, may be understood in solving, by the globe, such questions as those which are contained under the next problem.

PROBLEM XIII.

CELESTIAL GLOBE.

To find that portion of the equation of time which results from the obliquity of the ecliptic.

Repeat sidereal day, (def. 83); Solar day, (def. 84); Apparent noon, (def. 85); True or mean noon, (def. 86); Equation of time, (def. 87), reading its note.

RULE.—Find the sun's place in the ecliptic, bring it to the brass meridian, and count the number of degrees from the first point of Aries to the brass meridian on the equinoctial and on the ecliptic: the difference, reckoning four minutes of time to a degree, is this portion of the equation of time. If the degrees on the ecliptic exceed, the sun is faster than the clock: if the degrees of the ecliptic are deficient, the sun, (as far as this circumstance is concerned,) is slower than the clock.

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1. When the sun has no declination, (*i. e.* at the equinoxes,) it is evident that, as far as the obliquity of the ecliptic is concerned, sun-dials and clocks agree: but supposing that from the 21st March until the 19th April the sun had proceeded 30° in the equinoctial instead of in the ecliptic, how much later (in absolute time) would he have come to any meridian on that day?

2. How much sooner (regarding the absolute duration of time) is the sun on our meridian on the 5th June, than he would have been had he fulfilled his 75° of apparent motion (from the 21st March to that date) in the equinoctial line?

3. Does the sun, on the 10th July, come to the meridian before or after the time at which he would have come to it, had he, from the 21st March, performed his apparent course of 108° in the equinoctial: *i. e.* had the earth's axis been perpendicular to the plane of its orbit?

4. What is this portion of the equation of time on the 6th and 28th September, 1st November, 21st December, and 16th February?

5. Refer to the note to definition 87, and find, by the globe, what portion of the equation of time is due to the obliquity of the ecliptic, and what portion, consequently, is due to the unequal rate of the earth's orbitual revolution, on the 1st September, the 1st November, (*a*) and the 12th February.

PROBLEM XIV.

CELESTIAL GLOBE.

The latitude, day, and hour being given, to find the azimuth or bearing of the sun or of a star, and its altitude.

Conversely.—To find the hour of a certain day, and the altitude of the sun, or of a star, the azimuth and latitude being given.

RULE.—Rectify the globe for the latitude: bring the sun's place for the last noon to the meridian, and set the index of the hour circle to 12. Turn the globe until the index have passed over the number of hours elapsed since the last noon; and the quadrant, affixed to the zenith and

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(*a*) Since, from both causes, the sun dial is — minutes faster than the clock (as given in that definition) and since the sun is only — minutes faster in consequence of the obliquity of the ecliptic; it is evident that the remainder is owing to the other cause.

made to pass over the sun's place, or the star, will show its altitude on the graduated edge, and its azimuth where the graduated edge cuts the horizon.

Conversely.—The pole being elevated to the latitude, and the sun's place being brought to the meridian for setting the index to noon,—let the quadrant be made to cut the horizon in the given azimuth: then, the sun's place, or the star, being brought to coincide with its graduated edge, it will point out the altitude, whilst the index is showing the hour.

⁂ At noon and midnight the azimuth of the sun is nothing. At any time after culminating the altitude and azimuth of the sun, or of a star, are such as they were at a corresponding interval before culminating, so that the pupil may always find the azimuth and altitude of the sun for a morning hour by taking those of the corresponding afternoon hour. It is true the sun's motion in the ecliptic, and, consequently, his change of declination are going on; but they are insignificant for so small a portion of time.

1. Find the azimuths and altitudes of Algol (β Persei) and Vega (α Lyræ) at 24m. past 5 P. M. of the 25th November at Edinburgh.

Find the altitudes and azimuths of the sun as required below:—

2. Madrid, 28th July or 15th May, at half past 3 P. M. and half past 8 A. M.

3. London, 19th November or 22d January, at three quarters past 1 P. M. and a quarter past 10 A. M.

4. Cape of Good Hope, 19th November or 22d January, at three quarters past 1 P. M. and a quarter past 10 A. M.

"I well remember going on deck with a certain flutter of spirits to see, for the first time in my life, the sun to the northward, and moving from right to left, instead of left to right. No one doubts that the earth is round; yet these conspicuous and actual proofs of its rotundity always amuse the fancy and frequently interest the judgment. * *

"At one time the sun, even at noon, was seen creeping stealthily along, low (a) down in the horizon, at another his jolly countenance was blazing away right over head. On the 5th May when our latitude was 17⅓° north, the sun's declination was 16¼°. * * * Shadows we had none." Capt. Hall's Fragments, Vol. 1, 2d Series, p. 149.

(a) That is when the ship was yet in the high latitudes.

"The gradual rise, night after night, of new stars and constellations, belongs to a still higher order of curiosity; for it not merely places well known objects in strange positions; but brings totally new objects of contemplation before our eyes." *Ibid.*

5. What are the azimuths and altitudes of *a* of Crux, Canopus, Sirius, and Rigel, at Swan River (Western Australia) lat. 32° S., at three quarters past 9 P. M. 16th February?

6. Latitude 74¼° south on 13th December. Find the azimuths and altitudes of the sun at noon, (*b*) at 10 P. M., at midnight, and at 2 A. M. of the next day.

Any heavenly body having more degrees of declination in the same hemisphere with a given place than correspond to the latitude of that place, will have the same azimuth or bearing twice before and twice after it culminates. Hence the sun, during several days of the year, when to the north of places lying between the northern tropic and the equator, will appear at those places on the same point of the compass twice in the forenoon and twice in the afternoon; and the shadow of any church-spire or other perpendicular object must consequently "go back;" retracing, for instance, a part of the progress which it made from the south towards the west, whilst the sun was making his way from the north towards the east; as his bearing from the north becomes less again before he culminates.

Had the "sun-dial of Ahaz," (Isaiah xxxviii.) been situated in the torrid zone, instead of at Jerusalem, (latitude 32° N.) the circumstance of the shadow of some of its "degrees" being brought back, would not, at a certain time of year, have been miraculous. The astronomical Babylonian princes sent ambassadors to Hezekiah "to enquire of the wonder that was done in the land" on occasion of that king's recovery from sickness.

Conversely.

7. Greenwich, 1st January. What is the hour at which Dubhe (*a* Ursæ Majoris) has azimuth 35° north towards

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(*b*) Here the sun was north at noon and south at midnight.

east; and at what time and with what altitude will it again have the same azimuth before it culminates?

8. My garden wall, at Blackheath, stretches 20° north of west: at what hour on the 21st of June does the sun begin (a) to shine on the grape vine trained over its southern face; and during how many hours does it shine upon it on that day, there being no impediments?

9. In latitude 35° north, on the 23rd September, at what hour will Capella bear exactly north-east; and at what hour, and with what altitude, will it again have the same bearing before it culminates?

10. At what hour on the 1st July will the sun first appear east-north-east at Port Royal, Jamaica, and at what hour of that day will he again have this bearing, after having cast shadows to the north of west-south-west?

11. At Lima, on the 20th January, at what hour of the morning will the sun cast shadows 70° from the north towards the west, and at what time will shadows again have this bearing, after having been directed farther towards the south?

12. At 3 o'clock P. M. of the 16th January, in a certain longitude on the parallel of 40° south, I observed the sun's "magnetic azimuth" to be 90°, or due west: how far was the sun, really, at that time, from this prime vertical (b); and how much, and in what direction, did my azimuth compass vary from the true meridian in that situation?

PROBLEM XVI.

TERRESTRIAL GLOBE.

Having the latitude, to find the two days of the year which are of a given length, and in what time that length of day is altered by a certain quantity.

Repeat again definitions 8, 13, 19, 11, 14, 33, 34.

(a) It is evident that the sun will begin to shine on this wall when his azimuth is opposite the other end, viz. 20° S. of E. or more properly 70° E. of S.

(b) The azimuth arc passing through the east or west is called the Prime Vertical.

RULE.—If the given length of day be the longer, subtract the given difference to find the shorter day:

Bring the given place to the brazen meridian, set the index to 12, and turn the globe until the index have passed over so many hours as are equal to half the shorter day. Keep the globe from rotating, and elevate the north or south pole until the given place coincides with the eastern edge of the terminator: the elevation of the pole will show the declination on the shorter day. Continue the rotation of the globe for half the difference, *i. e.* until the index have completed half the length of the longer day; and the pole, elevated as before to accommodate the given place to the terminator, will show the declination on the longer day.

There are two days corresponding to each length; viz. one on each side of the summer solstice. If the days be increasing, take the interval between those two unequal days on which the sun is advancing towards the summer solstice; if the days be decreasing, take the interval in which he is declining from it in like manner.

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1. What two days of the year are each 8 hours long at London; and in what time is the day increased by 2½ hours?

Here, by bringing London to the meridian, setting the index, and turning the globe 4 hours, I find that, in order that London may coincide with the terminator, the south pole must be elevated 22½°; answering to the 7th January, and 6th December. Turning the globe 1¼ hour more, I find that, to bring London to the terminator, it is necessary to have that pole elevated only 9¼°, and this answers to 25th of February, and 17th October. As the place is north, and the days are increasing, I take the interval between 7th January and 25th February, and find it 49 days.

2. In what time will the day increase 2½ hours more, when thus increased to 10½ hours?

Here it will be found that the increase will be made in much less time, owing to the more rapid change of the sun's declination.

3. On what two days of the year is the sun above the horizon for 15 hours at Greenwich; and how many increasing days will elapse before he continues above the horizon one hour more?

4. What two days of the year are each 13 hours long at Petersburgh; and in what time, from the latter of these two days, will the day have decreased 4 hours?

5. What is the difference in the declination of the sun when he rises (*a*) at 7 o'clock at Stockholm, and when he rises at 3 o'clock there, and consequently gives 8 hours longer day; and how many days must elapse before this 18 hours' day again dwindles to the length of the former?

6. What two days of the year are each 16 hours long at the Cape of Good Hope?

7 On what two days does the sun set at half-past 8 at Edinburgh; and in how many shortening days will he set at half-past 7?

8 In what time from the latter date will the sun set, at Edinburgh, at half-past 6?

PROBLEM XVI.

TERRESTRIAL GLOBE.

To find the situations of the periœci, antœci, and antipodes of the inhabitants of any place; and to explain some of the various phenomena in those situations.

Learn definitions 77, 78, 79.

Rule.—Make the poles of the globe coincide with the terminator, and bring the given place to the eastern edge; thus the graduations for amplitude will serve to point out latitude. If the given place be in north latitude, observe that latitude as shown in degrees of distance from the east towards the north, and the same number of degrees to the south of the east point will show the antœci; an equal number of degrees from the western point towards the north will show

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(*a*) It will be recollected that the sun sets on any day so many hours after noon as he rises before noon.

the periœci; and the same number of degrees counted from the west toward the south will give the antipodes.

If the given place be in south latitude, for *north* read *south*, &c.

⁂ If the hour-circle be so fixed as to prevent the poles' being placed in the terminator, the antœci may be seen by bringing the given town, &c. to the meridian, and observing the place also coinciding with the meridian, which corresponds in latitude of the opposite hemisphere. The index being now set to 12, let the globe be turned half way round, and the antipodes will be seen occupying the position of the antœci, and the periœci be substituted for the given place.

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1. Required the antœci, periœci, and antipodes of the island of Burmuda.

Antœci a little north-west of Buenos Ayres, &c. &c.

2. Where are the antœci, periœci, and antipodes of the west of Newfoundland?

3 Where are the antœci of the Cape of Good Hope?

4. Where are the periœci of New York?

5. Where are the antipodes of Greenwich?

When our clocks are striking 6, and the summer sun is not yet set, our *antœci* and *antipodes* have him just so much depressed as we have him elevated; but whilst it is the darkness or twilight of winter *evening* to our antœci, it is the darkness or twilight of winter *morning* to our antipodes.

If the clocks are striking 6, and our winter sun has gone down, he is just so much elevated to our *antœci* and *antipodes* as he is depressed below our horizon; but he is a summer evening sun to our *antœci*, and a summer morning sun to our *antipodes*.

Our *periœci*, on the contrary, agree with us in season; but they are the antipodes of our antœci, and have opposite hours to theirs and our own. Hence, like our own antipodes, they are always as near to noon as we are to midnight; but at the two instants of 6 o'clock of every twenty-four hours, their elevation or depression of the sun is equal to our own, except that their ascending sun is our descending one, and *vice versâ*.

The night sky of our antœci and antipodes is totally different from ours, the stars which never rise to us never setting to them, and *vice versâ*; that of our periœci corresponds with ours, except that it is presented to them twelve hours later, and the moon, consequently, has considerably changed her place amongst the stars.

To exhibit some of the Phænomena.

RULE.—Find the antœci, periœci, and antipodes, by the rule just given, and mark each of them with a small dot of ink. Elevate the pole to the declination of the sun; bring the given place to the meridian, and set the index to 12; then turn the globe eastward until the index have passed over six hours. Affix the quadrant to the declination in the zenith, and it will be found by applying it to these situations (whether elevated or depressed) that they are circumstanced with regard to sun-light as just described.

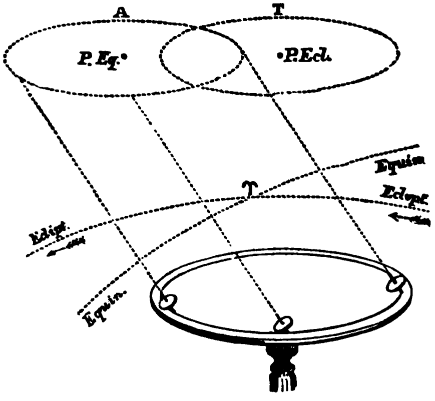
6. What are the positions as to sun-light, respectively, of the antœci, periœci, and antipodes of the inhabitants of Greenwich, when it is 6 o'clock P. M. on the following days: 1st March, 25th May, 21st June, 21st December?

7. Supposing the moon to be full and therefore opposite to the sun, when it is 6 o'clock P. M. at Madrid on the 28th October; whether are the situations of Madrid and its antœci, periœci, and antipodes in moon-light or in sun-light; and, of those which have moon-light, which places have an *ascending*, and which a *descending* moon? (*a*)

(*a*) Here, the pole having been elevated to the declination of the sun, and the place of that luminary being thus represented by the degree of his declination on the uppermost point of the brazen meridian; the moon's place, on this occasion, is represented by the diametrically opposite point of it, and she is giving light to all below the terminator; those quitting sunlight entering into her light, &c., and any place having her at an elevation corresponding with its depression below the terminator. (See 8th question, p. 122.)

POLES OF THE EQUINOCTIAL—POLE STAR—FIXED STARS—POLES OF THE ECLIPTIC—CELESTIAL LATITUDE AND LONGITUDE.

There is one circumstance which may yet have been a stumbling-block to the enquiring minds of our young friends: viz. *the unvarying direction of the earth's axis to one particular point in the sky;* and the consequent unvarying correspondence of the parallels of latitude on our earth with the parallels of declination in the sphere of stars around us, *notwithstanding the earth's motion in her yearly orbit of nearly* 600 *millions of our miles.* We would recommend a revisal of the familiar illustrations given in G and H, on p. 5, and request attention also to what follows.



As our tee-totum traverses the groove with its axis inclined, (as proposed on p. 108. and illustrated there and by the annexed figure,) it is evident that the upper point of the peg must be directed to the different parts of a circle which may be traced on the ceiling, and which exactly corresponds to the table in size; but which is *not immediately over the groove or orbit,* being removed from a position immediately over it just so much as the axis is inclined, or 23° 28′.

Suppose the ceiling, under these circumstances, to be raised to the height of the house; the circle so described in the ceiling by the pointing of the peg during its progress round the table, would now *appear* to be considerably less; although, of course, really retaining its size as well as its bearing. Now, suppose the ceiling could, by any possibility, be raised a mile, whilst retaining the bearing of its position, viz. with the said circle exactly 23° 28′ towards the side of the table: would not the circle vanish, or at least dwindle into a point? why so? only because of the greatness of its distance when compared with its dimensions; that is, with the dimensions of our table or orbit.

Suppose a tiny individual to be perched on the upper extremity, or north pole, of our peg: in the former instance, before the removal of the ceiling, his head would be directed to the several points of the circle in the ceiling (see A in the figure); and if we conceive the stars to be so near as that their distance, when compared with the size of his tee-totum world, or its orbitual groove, were *in* the *un*elevated ceiling, it is evident that each day in the year might have its separate "pole star." Now, so great is the distance of the circle thus elevated, that his head will appear, during each of his 366 daily rotations to be under the same distant point.*

We may thus understand that the orbit of our earth, the diameter of which averages 190 millions of miles, if viewed with such eyes as our's at a distance equal to that of the pole-star, would not appear greater than our distant dwindled circle, or than the pole-star appears to us,—a glittering speck!

Now, if our change of station of 190 millions of miles thus produces no apparent change of place (or parallax) of the pole star; it is evident that if the other stars be as distant as this star, no apparent change of place from this cause can be observed in them: hence their designation, "fixed stars."

But another important circumstance remains to be referred to, and explained; and we think the pupil will now readily receive it, when we refer to the point into which *the circle similarly described in the ceiling, and immediately over the groove, or orbit, on the table,* would dwindle if similarly elevated. It is "*the pole of the ecliptic,*" (see T in the preceding figure,) and is consequently situated (as laid down on all our celestial globes) just 23° 28′ distant from the former point, or pole of the equinoctial, to which our inclined peg or axis is directed.

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* The polar point in the heavens is, however, not strictly invariable: we shall soon attempt very familiarly, to illustrate this.

"Unluckily, the early astronomers have employed *also* the words *latitude* and *longitude* in their uranography, in speaking of arcs of circles not corresponding to those meant by the same words on the earth; but having reference to the motion of the sun and planets amongst the stars. It is too late now to remedy this confusion which is engrafted into every existing work on astronomy: we can only regret it and warn the reader of it." *Sir J. W. Herschel's Astronomy*, p. 58.

N. B. The terms *celestial longitude* and *celestial latitude* referred to and censured by the great authority quoted above, regard the ecliptic and its pole in the same manner that right ascension and declination refer to the equinoctial and the pole of the equinoctial; or, as the latitude and longitude of our earth's surface refer to its equator and the pole of its equator. Accordingly, the circles parallel to the ecliptic on the celestial globe, are "parallels of celestial latitude;" and the lines drawn perpendicularly to the ecliptic (generally through every *fifteen* of its degrees) and centering in "the poles of the ecliptic," are lines of "celestial longitude," which is reckoned in signs and degrees, eastward only, from the first point of Aries. Declination and right ascension are, however, in most cases more convenient, and most employed.

A star may thus be north of the equinoctial, and yet have south latitude; or it may be south of the equinoctial, and, notwithstanding, have north latitude; that part of the heavens which is north of the ecliptic being called the *northern* hemisphere, and that south of the ecliptic the *southern* hemisphere.

PROBLEM XVII.

CELESTIAL GLOBE.

To find the latitude and longitude of a star or planet.

Conversely. The latitude and longitude of a star, &c. being given, to find that star, &c.

Read p. p. 151–3. Learn Memorial Verses, "The Ram and Bull, we'll keep in view," &c. (Appendix.)

Rule.—Bring that pole of the ecliptic which is of the same hemisphere with the star's latitude, to the upper semicircle of the brazen meridian, and elevate the pole of the equinoctial 66½°: the ecliptic will now coincide with the horizon, and its pole with the zenith. Affix the quadrant of altitude to the zenith; and, keeping the globe steady, make the quadrant coincide with the given star; thus the graduation of the quadrant will show the star's latitude, and its longitude will be seen where the quadrant cuts the ecliptic in the horizon.

Conversely. The latitude and longitude being given to find the star:—Place the O of the graduated edge of the quadrant on the given longitude in the ecliptic, and its 90th degree (or pivot) on the ecliptic pole of the star's hemisphere; then, underneath the degree which corresponds to the given latitude the star will be found.

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1. What are the latitude and longitude of Vega (*a* Lyræ)?

Ans. North latitude 62°, longitude 12° ♑, or 9 signs, 12°.

2. What are the latitude and longitude of *a* of Crux?

Ans. S. L. 53°, longitude 10½° ♏, or 7 signs, 10½°.

3. What are the latitudes and longitudes of the following stars?

Capella
β Tauri
Pollux

Fomalhaut
Rigel
Canopus

N. B. The sun being *in* the ecliptic, has no latitude ; the moon (*a*) never has more than 5⅛° of geocentric latitude : the apparent motions of the planets, with the exception of those of three of the asteroids, (*b*) are always within 8° of the ecliptic ; and for the purpose of marking their ever shifting positions, lines of latitude and longitude are drawn (on most celestial globes) through every degree of this range, forming an appearance of checker-work.

4. Find, on the globe, from the five right-hand columns of the 13th page of White's Ephemeris, given on our page 51, the places of Saturn, Jupiter, Mars, and Venus, on the 1st June, and the place of Mercury on the 25th June ; and record the stars, (large or small) near to which they were then appearing.*

Conversely.

5. What stars have the following latitudes and longitudes?

20¼°	S. L.	Long.	0	signs	19°
39¼	N. L.	„	10	„	4
10	N. L.	„	3	„	17½
44½	N. L.	„	7	„	10⅛
40½	S. L.	„	11	„	12½

PROBLEM XVIII.

CELESTIAL GLOBE.

Having the longitudes and latitudes of the planets, to find their times of rising and setting ; their amplitudes, azimuths, &c., at any given place.

Repeat p. 25 (def. 1) : also def. 7.

(*a*) On account of the nearness of the moon her place is much affected by parallax to those who are far from where she is vertical. (Note G. p. 18.)

(*b*) The inclination of the orbit of Pallas to our ecliptic plane is as much as 43° 35′.

* Thus, Saturn, just half a degree south of the small star — of Serpentarius ; Mercury —° south of Pollux.

Rule.—Elevate the pole for the latitude: find the places of the planets, as in the last problem, from an Ephemeris, and stick a very small piece of paper,* inscribed with the symbol of its planet, upon each place. Bring the sun's longitude to the meridian, and the index to 12.

Then, whilst the sun is so placed, if Venus or Jupiter (whether above or below the horizon) lie to the east of the plane of the meridian, it is an evening star; if it lie to the west of that plane, it is a morning star. Cause the globe to rotate westward. As these several symbols of the planets arrive at the eastern horizon, the upper meridian, and the west, their times of rising, their amplitudes, azimuths, culminations, and setting, may be noted as in Probs. IX. & XIV.

1. On the 13th October, 1834, the longitudes and latitudes of the planets were as follows: were Jupiter and Venus morning or evening stars; and at what hours did they and the other planets rise and set at Greenwich?

♄	14°	♎	31′	lat.	2°	N.	14′
♃	11	♊	25	,,	0	S.	54
♂	12	♋	0	,,	0	N.	37
♀	6	♐	22	,,	3	S.	45
☿	7	♏	0	,,	1	S.	16

2. On 1st February, 1836, the longitudes and latitudes of the planets were as follows:

♄	5°	♏	9′	lat.	2°	N.	31′
♃	7	♋	14	,,	0	N.	7
♂	0	♒	54	,,	1	S.	3
♀	10	♓	21	,,	1	S.	25
☿	28	♒	37	,,	0	S.	33
♅	29	♒	29	,,	0	S.	44

Were Venus, Jupiter, and Mercury, morning or evening stars; what were their times of rising and setting at Edinburgh; and what the times of culmination of Mars, Saturn, and Uranus?

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* If the paper be cut of a triangular form, a corner may be put very exactly on the place of the planet: common writing paper, if wetted, will often adhere sufficiently; but a little piece of medallion wafer, such as those now so much used, will be better.

3. What was the time of Saturn's rising on the 25th June, 1840 (for his place see our page 51); and what were his azimuth and altitude at half-past 9 P. M., when I was viewing his ring?

⁂ Whether, under some circumstances, the morning star may be seen: or, whether it even rise before the sun, although to the west of that luminary, *may* depend upon the latitude of the place and the planet's declination: This may be illustrated by the following:—

4. Venus's longitude, on the 21st March, was 20° in ♒, and her latitude 1° south: at what times* will she rise on the morning of that day at Madrid, latitude 40°; Land's End, latitude 50°; Petersburgh, latitude 60°; and at the north part of Lapland, latitude 70°?

PROBLEM XIX.

TERRESTRIAL GLOBE.

Having the instant of the immersion or emersion of a satellite of Jupiter, to determine those situations from which it may be viewed.

Read again p. 53, in explanation of p. 52, and p. 50, in explanation of p. 51.

These eclipses furnish an excellent means of determining longitude, since, on account of Jupiter's distance, no change of place on the earth can effect the apparent relative positions of him and his moons, (M on. p. 18); but to observe them with precision, a telescope of considerable magnifying power must be used, and such a telescope requires perfect steadiness: hence these phenomena are not available on ship-board.

To have an eclipse of a satellite of Jupiter distinctly visible, "the sun must be at least 8° below the horizon, and Jupiter not less than 8° above it at the same time.†" Hence we will take the following method:—

RULE 1.—If the latitude and longitude of Jupiter be given, find by the celestial globe his R. A. and declination, and elevate the pole to his declination. Find, from the difference of Jupiter's R. A. and the sun's, the time of his last being on the meridian,* and reckon the hours between this time and the time of the immersion, &c. Bring the place, the time of which is given, to the brass meridian, and set the index to 12, (as a mark). Cause the globe to rotate eastward so many hours as the time of immersion, &c. is past the previous culmination of Jupiter:—All places now above the terminator are those to which the planet's beams are extending:—Note down the principal of them, excepting those which, not being more than 8° above the terminator, do not have him sufficiently elevated.

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* It will be recollected that the first point of Aries (the sun's place) rises at 6 o'clock every where on that day.

† Nautical Almanac.

2. Now, elevate the pole (north or south accordingly) to the sun's declination; bring the sun's "place" to the brazen meridian, set the index to 12, and turn the globe as many hours eastward as the time of the immersion, &c. is past the last noon. This will show the position of the earth's surface with regard to sunlight at the time of the immersion, &c; and all places now above the terminator, or within 8° below it, which have been inserted in the foregoing list, must be struck out of it, as having the phenomenon hidden from them by daylight: the remaining places only being those at which it may be viewed.

1. I find (on p. 52) that there was an emersion of ♃'s first satellite at 15d. 11h. 13m. 40s. of June; or about ¼ past 11 P.M. of 15 June; and, looking at p. 51, I find that his R. A. is then 14h. 30m. and his declination about 13½° S. Find, from these data, from what situations this emersion might have been viewed?

Here having elevated the S. pole 13½°, and having found that the ⊙'s R. A. is 85° or 5h. 40m.; and that, consequently, ♃ was on the meridian, 8h. 50m. after the ⊙, or at 50m. past 8 P.M., I bring Greenwich to the brass meridian, set the index to 12, (as a mark,) and turn the globe 2h. 24m. eastward, such being the interval between the time of ♃'s being on the meridian, and the emersion's taking place. I now note down the places above the terminator, as being those that have ♃ above their horizon, omitting all within 8° of the terminator; they are the following:—South America, North America, except the N. W.; Africa and Madagascar, except the eastern parts, and all western Europe.

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* This time of culminating will not differ materially in one day; we take the last culmination to avoid the inconsistency of reversing the globe's motion.

But, following the 2d section of the rule, I find that it is needful to strike out North America, the West Indies, and the N. W. of South America, as well as the extreme north of Europe; since they were in sun-light, or strong twilight, at the time of this eclipse.

2. Suppose that on the 21st December, in a certain year, there will be an immersion of a satellite of Jupiter at 5 A.M. (Greenwich time); and that Jupiter's R. A. is 150° or 10h., and his declination 12° N. From what situations may this immersion be viewed? (*a*)

3, On 4th August ♃'s longitude being 11 signs 14° and his latitude 1¼° south, there was an eclipse of his second satellite when it was 10 o'clock at night at Petersburgh. Where might it have been viewed? (*b*)

4. June 8, 9h. 39m. 8s. ♃'s 1 Sat. emers. (see p. 52.) Find ♃'s R. A. and declination from p. 51 (*c*); and from these data determine the situations from which this emersion might have been visible?

5. In 1838, January 17, 19h. 14m. 34s.; ♃'s 1 Sat. Im. R. A. 11¼h. declination 5¾° north. Find where this immersion was visible?

(*a*) Here Jupiter will culminate — hours before the sun; but the immersion will take place only 7 hours before the sun culminates.

(*b*) Here (from his longitude and latitude) I find Jupiter's R. A. will be such that he culminates — before the sun; but the eclipse takes place 10 hours after the sun culminates; hence the difference between the times of Jupiter's culmination and the eclipse of his satellite will be 10 hours added to — hours.

(c) It must be remembered that the R. A. is given for every day; but declination (as well as longitude and latitude) for every 6th day only; in this case we must take the declination given for the 7th day, as the nearest to the 8th day.

CELESTIAL GLOBE.

Exercises, chiefly recapitulatory, on the Right, Oblique, and Parallel positions of the Sphere.

RIGHT SPHERE.—Latitude 0; the poles in the horizon.

Repeat def. 49.

1. What inhabitants of the earth have this position of the sphere; and what stars are *constantly* above or below their horizon?

2. What (strictly speaking, and also disregarding refraction) is the diurnal arc of any fixed star at the equator: and is the diurnal arc of a star as shown by the index of a globe strictly correct?—(*See def.* 83 *and its note.*)

4. What is the diurnal arc of the pole-star at the equator, supposing the polar-point not to be elevated by refraction?—(*See 5th question of Prob.* V. p. 77.)

5. What (invariably) is the diurnal arc of the sun there?—(*See def.* 84.)

6. What is the diurnal arc of the moon there;* and why does it differ from the diurnal arc of the sun, and still more from the diurnal arc of a fixed star?—(*See def.* 88, *and its note.*)

7. What is meant by the right ascension (R. A.) of the sun, or of a star, or planet?

8. In strictness, does the R. A. of the ⊙ for any day coincide with that degree of the equinoctial which culminates with him? why, or why not?

9. Find, by the globe, whether the declination of a star, &c., affect its R. A. (*for instance β Aurigæ and Betelgeux.*) and how much longer the day is at the equator when the ⊙ has $23\frac{1}{2}^\circ$ north declination, than when he has $23\frac{1}{2}^\circ$ south declination?

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* The moon, if watched, will be found, night after night, to have removed about 13° (nearly 24 times her apparent diameter) to the east of the position she occupied amongst the stars at the same hour of the night before: hence the earth must turn about 50 minutes more, to bring her to the meridian, after the star with which she last came to the meridian has arrived there.

10. Find, by the globe, the difference in a right sphere between the rising or setting amplitude of any heavenly body and its declination?

11. On what two days is the ⊙ vertical at the equator; and when he is on the meridian but not vertical, what is his depression from the zenith (*i. e.* his "meridian zenith distance") always equal to?

12. Suppose a house at Quito to stand with its façade duly north, during which months in the year is the back of it entirely shaded; and out of which windows must the inhabitant look to see the full moons of those months?

13. What is the greatest meridian zenith distance of the sun at the equator; what, consequently, his least meridian altitude; and on what two days of the year does this occur?

OBLIQUE SPHERE.—The north or south pole elevated according to the latitude.

Repeat def. 51.

1. How many degrees does the altitude of the pole-star change, in the course of the sidereal day, at any place having an oblique sphere?—(*See explanation to question* 1 *on page* 96.)

2. What is the diurnal arc of any star in the equinoctial to the inhabitants of an oblique sphere?

3. Find (by bringing them severally to the meridian) what are the right ascensions of δ of Orion, *a* of Orion, (Betelgeux,) and Castor, (*a* of Gemini,) and what are the oblique ascensions of these three stars in latitude 37° north, and their several ascensional differences?—(*Def.* 56 *and note.*)

4. Find, by using the index, how long these several stars are above the horizon in that latitude; and contrast their several "descensional differences" with their several "ascensional differences"?

5. Turn into time the *sum* of the ascensional and descensional differences of either of these two northern stars (Castor and Betelgeux); and compare that time with the

excess of the star's diurnal arc above the 12 hours' arc of δ of Orion ?

6. The sun, on the 21st June, as may be seen, rises at the equator with the 90th degree of the equinoctial: with what degree of the equinoctial does he rise in latitude 60½° north? Compare this ascensional difference, when turned into time, with the excess of the half-day in that latitude above the 6 hours' half-day of the equator ?

7. The sun, on 3d. November, at 6 o'clock, is setting at Quito with the 218th degree of the equinoctial. The inhabitants of the western part of Jamaica, having the same longitude, have exactly the same time of day at that instant; but, to them the sun has already set:—with what degree of the equinoctial has he set there, and, consequently, how many minutes before 6 o'clock ?

8. What are the ascensional and descensional differences of the ⊙, in any latitude (N. or S.,) on 23rd September and 21st March; and what, consequently, the times of his rising and setting ?

9. Find the ⊙'s oblique ascensions at Madrid and at London on 21st December; and, by contrasting them, find the difference in the length of half that day in the latitudes of those cities ?

10. Supposing the moon's place in the sphere at the time of her rising to be given you; can you determine in the same way (viz. by her ascensional difference) her exact diurnal arc ? why, or why not ?—(*Note to definition* 88.)

11. If the moon's orbit, or monthly path, were so placed (as it may be) that, being in conjunction with δ of Capricornus one night at rising, she could, four nights afterwards, be rising in conjunction with δ in the string of Pisces; what differences would there be in her oblique ascensions, on those nights and the intervening ones, in latitude 61° N.; and what, consequently, would be the difference in the times of her rising on those occasions ?

12. Find, by the oblique descensions of these two stars,* the difference in the times of the moon's setting in that latitude, if her orbit were so situated as to bring her into exact conjunction with them ?

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* Viz. δ *Capricorni* and δ *Piscium*.

13. Find, from the ascensional or descensional difference of Capella, how much more than half of the sidereal day that brilliant star spends above the horizon of latitude 30° north; and how much less than half in latitude 30° south?

14. Just so many degrees as an inhabitant of the equator travels on his meridian (northward or southward) his zenith point is removed from his former zenith point in the equinoctial: since, then, the meridian zenith distance of the equinoctial is thus always equal to the latitude, what is its altitude above the horizon always equal to?—(*N. on p.* 2.)

15. Of what declination, or distance from the equinoctial, must that star be which cannot rise, or cannot set, in latitude 50°, and what relation must the declination of such a star bear to the latitude?—(*See remark on p.* 130.)

PARALLEL SPHERE.—The polar point in the zenith; and the equinoctial, consequently, coinciding with the horizon.

Repeat def. 50.

1. What stars are constantly above or below the horizon of the north pole?

2. How high is the sun at mid-day or midnight of the 21st March, or 23d September?

3. What is the altitude of the sun at the north pole on 5th May, the 21st June, and the 16th October, at any *times* on those days?—(*See remark on p.* 132.)

4. In what time, exactly, do the stars appear to move around above the horizon at the north pole?—(*Def.* 83.)

5. In what time does the sun appear so to move around it, and why?—(*Def.* 84.)

6. In what time does the moon, if above the horizon, appear to do this, and why?—(*Def.* 88.)

7. At what periods of the year does the sun take the fewer days to alter his apparent altitude there?

8. If the moon move around the earth near the plane of the ecliptic in about four weeks, during how long a time is she constantly above the horizon there?

9. When the moon is full she is nearly in the part of the ecliptic exactly opposite to the sun's place: how high is she at the north pole when exactly full and without latitude,* on the 16th November?

10. When the full moon is most wanted in the polar regions, she is most advantageously placed in the sphere: what would be her altitude at the north pole if full in the middle of its long winter period?—(*See quest.* 9.)

11. How long is the sun so depressed below the horizon of the north pole as not to afford twilight?—(*See page* 120.)

12. Supposing the moon to be about to be full on the 21st December, with what phase will she rise there a week before; and with what phase will she set a week afterward?—(*Def.* 102.)

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* It must be recollected, that the *latitude* of heavenly bodies is their distance from the *ecliptic*.

For Questions on the TRADE WINDS, TIDES, MOON'S NODES, PRECESSION OF THE EQUINOXES, &c., *see Problems, Section III.*

SOME OF THE PROPERTIES OF BODIES, AND THEIR PHENOMENA.

"Nature is but the name for an effect whose cause is God."
Cowper.

"All natural occurrences, in the skies, and on the earth, in the organic, and in the inorganic world, are determined by the relations of elements and the actions of forces of which the rules are prescribed. * * * All things are ordered by number, and weight, and measure. 'God,' as was said by the ancients, 'works by geometry:' the legislation of the material universe is necessarily delivered in the language of mathematics: the stars in their courses are regulated by the properties of *conic sections*, and the winds depend on *arithmetical* and *geometrical progressions* of elasticity and pressure."—*Whewell's Bridgewater Treatise*, pp. 7, 8.

"An impression of adaptation, of mutual fitness, of conspiring means, of preparation and completion, of purpose and provision * * is suggested by the contemplation of every part of nature."—*Ibid.* p. 13.

"The first stage of man's life is a state of constant and curious excitement; * * the powers of reflection and comparison are lost in the incessant activity and unexhausted vigour of observation. * * * After a season, attention is drawn from the discovery of what is new, to the examination of what is familiar; * * the great work of comparison begins."—*Cab. Cyclop. Mechanics*, pp. 2, 3.

MATTER, Lat. *Materia.*

"*Matter* is the general name which has been given to that substance which, under forms infinitely various, affects the senses * * * When we speak of *bodies* we mean those things, whatever they be, which excite in our minds certain sensations; and the powers to excite those sensations are called *properties* or *qualities*."—*Ibid.*

Matter is described, as :—

1. Ponderable, or having appreciable weight.
2. Imponderable.

The imponderable forms of matter are
HEAT, LIGHT, ELECTRICITY, MAGNETISM.

The three general forms of ponderable matter are
The GASEOUS, the FLUID, and the SOLID.

These several forms are conjectured to arise from the combination of varied portions or degrees of *caloric*, the imponderable agent to which the phenomena of heat are ascribed.

ATOM—ATTRACTION OF COHESION—REPULSION.

B The word *atom* (signifying that which cannot be farther divided) is applied to describe an ultimate particle of matter; *i. e.*, a particle (as far as human means are concerned) indestructible and unchangeable. Thus, bodies the most dense, as the metals, &c., by the application of heat may be dissipated into the invisible or gaseous condition; but again, by the abstraction of heat, they are reconverted into their former state of solidity.

1. The word "Molecule" seems to be more generally appropriate than the word "Atom." There cannot be such a thing as an atom of any chemical compound, such as water, vermilion, &c.; since each ultimate particle of such compound must contain, at least, one "atom" of each of its ingredients.

2. Several of the gases, (such as the carbonic acid gas, sparkling in soda water, champagne, &c.) have lately been reduced to the solid state by violent pressure and intense cold.

3. "There is no solid substance known which, by a sufficiently intense heat, may not be melted, and finally dissipated in vapour * * But solids, themselves, by the abstraction of heat, shrink in dimension, and at the same time become harder and more brittle, yielding less to pressure, and permitting less separation between their parts by tension. * * * It is heat, and heat alone, which holds the particles of all bodies at that distance from each other which is necessary to allow of compression; which in fact gives them their elasticity, and acts as the antagonist force to their mutual attraction.

which would otherwise draw them into actual contact, and retain them in a state of absolute immobility and impenetrability."—*Sir J. F. W. Herschel's Discourse*, pp. 321—2.

C The ultimate particles of matter are thus demonstrably not in contact—" Since all matter may be made to fill a smaller volume by cooling, it is evident that the particles of matter must have space between them."—*Sir H. Davy.*

1. Take the quadrant of altitude and bend it: the molecules which compose that portion of its substance which is nearer to its *under* surface, are now evidently brought closer to each other; they could not, therefore, have been in absolute *contact* before.

2. The stone is not in absolute contact with the hand which is flinging it; and the fingers themselves do not fly off with the stone, only because the molecules which compose them are packed so closely, as to be sufficiently attracted to each other to resist the motion communicated to them in common with the stone.

D " Any visible mass of matter then, as of metal, salt, sulphur, &c., we know to be really a collection of dust or minute atoms by some cause made to cohere or cling together: yet there are no hooks connecting them, nor nails, nor glue; and the connection may be broken a thousand times by processes of nature or art; but is always ready to take place again: the cause being no more destroyed in any case by interruption, than the weight of a thing is destroyed by frequent lifting from the ground. Now the cause we know not; but we call it *attraction.*

"The phenomena of attraction, and its contrary, *repulsion,* particularly when occurring between bodies at considerable distances from each other, are as inexplicable as any subjects which the human mind has to contemplate." —*Dr. Arnott's Elements of Physics*, p. 13.

1. The forces of attraction and repulsion, acting between the ultimate particles of matter, and acting, therefore, only at extremely minute distances, are called *molecular forces.* Sometimes the words "*attraction of cohesion*" are employed to denote the former force: This force is not to be confounded with the attraction of gravitation, which acts universally, *i. e.*, at *all* distances, and quite independently of the *states* of bodies.—See *Gravity* (*Index.*)

THE AERIFORM, LIQUID, AND SOLID STATES.

F "All bodies consist of an assemblage of material particles, held in equilibrio by a cohesive force, which tends to unite them, and also by a repulsive force, probably caloric, the principle of heat, which tends to separate them. * * * It is evident that the *density* of substances will depend upon the ratio which the opposing forces of cohesion and repulsion bear to one another."—*Mrs. Somerville's Connex. of the Physical Sciences*, pp. 124—5.

1. It is important to distinguish the terms *mass* and *bulk*: the former refers to the *quantity* of matter in a body: the latter to the size of its outline or the extensiveness of its outward surface. Thus, a pound of lead is of equal *mass* with a pound of cork; but its *bulk*, owing to the compactness of its molecules, is comparatively inconsiderable.

G "When particles of the same kind of matter are at such distances from each other, that the cohesion which retains them is insensible, the repulsive principle remains unbalanced, and the particles have a tendency to fly from one another, as in *aeriform* fluids."—*Ibid.*

That department of science which treats of the phenomena presented by aerial fluids, is termed *Pneumatics.*

H "If the particles approach sufficiently near to produce equilibrium between the attractive and repulsive forces, but not near enough to admit of any influence from their form, perfect mobility will exist among them, resulting from the similarity of their attractions, and they will offer great resistance when compressed: properties which characterize *liquids*, in which the repulsive principle is greater than in the gases."—*Ibid.*

That department of science which treats of the equilibrium of liquids, is termed *Hydrostatics.*

1. At the depth of 1000 fathoms, the water of the sea has its bulk so diminished by the pressure of the water above, as that 99 gallons of it, if brought to the surface, would fill 100 gallons there. But 110 pints of common air, may be driven into the hollow ball, of one pint capacity, attached to an air gun; and a stand has been constructed for the support of a gas-light, into which so much gas might be condensed as would feed the flame for several evenings.

K "When the distances between the particles are still less, *solids* are formed, in consequence of the preponderating force of cohesion."—*Ibid.*

1. We may understand from G and H, that the term "liquid" is applied only "to such fluids as do not, though quite at liberty, attempt to dilate themselves beyond a certain point." Some fluids,

however, which exist even in the liquid form under ordinary circumstances of pressure, &c., become aeriform when that pressure is removed.

2. Ether exists as a liquid at the earth's surface, only because of the pressure of the atmosphere, and cannot be contained in an open vessel on the top of a lofty mountain.

Law of Pressure with respect to Fluids.

We conclude these remarks and selections with one very important as it regards our circumstances:—

Whilst pressure, applied to a solid, is transmitted only in that direction in which it is applied; in all fluids, whether aeriform or liquid, in consequence of the perfect freedom of their parts to move amongst themselves, each of the molecules "tends to recede from an excess of pressure on one side, and thus *bears upon all the rest, and distributes the pressure amongst its neighbours.*" Hence the remarkable hydrostatic law of "*equal pressure in all directions.*"

1. Suppose a bottle, of any shape whatever, to be made with twenty mouths, distributed over its surface as the quills of a porcupine; and nineteen of these mouths being corked, let it be exactly filled with water by means of the twentieth: any pressure tending to force a cork into this twentieth mouth, would tend *equally* to drive out *all* the others.

2. "The mass of the human body may be considered as an accumulation of solid atoms, each *separately immersed* in a fluid. This being the case, it follows that the pressure upon any portion of the external surface of the body, is propagated equally throughout its substance, by the intervention of the fluids which permeate it; and that each solid particle thus sustains pressures equal in every possible direction; so that, by reason of these pressures, it can have no tendency to move either in one direction or another."—*Moseley's Mechanics*, p. 277.

THE ATMOSPHERE, OCEAN, ETC.

M The globe we inhabit is encased in a *fluid*, as a kernel of a nut in its shell: and, of its immediate surface, not less than three-fourths are covered with a *liquid*. On this account it is highly important to an apprehension of some even of the most simple circumstances in nature, to attend particularly to the phenomena of the *fluid* state. It is hoped that the illustrations given, as they are necessarily few, may serve as hints for further enquiry.

1. "We are living in a fluid at the bottom of an ocean, as we see fish to be living in the sea, receiving large quantities of it at every instant into our bodies, and exhaling it. * * * Philosophers reasoned and speculated for 2000 years, on the subject of the atmosphere, before they discovered that it was material, a fluid, and had weight."—*Moseley's Mechanics*, p. 289.

2. Sir J. W. Herschel compares the relative *bulk* of the atmosphere to the downy skin of a peach when contrasted with the dimensions of the fruit.

3. At the level of the sea, 100 cubic inches of air, (about as much as would be contained in a box having its length, width, and depth, equal to the width of this book,) are found to weigh 31 grains; but the existence of this *mass* of air in such a *bulk*, is owing to the compression of the air above it. The *density* of the atmosphere rapidly decreases as we ascend. At the top of Mont Blanc, (an elevation of three miles,) the traveller has passed through half the mass of this ocean of air, although there are yet more than 40 miles of it above him.

4. The atmosphere has been aptly compared to wisps of wool, which being laid one upon another from the floor to the ceiling of a room, would half of them be contained in that portion of the pile which reached only a very few inches from the floor.

5. It is shown by experiments in pneumatics, that the pressure of the atmosphere at the average surface of the earth, is equal to a force of 15 pounds on every square inch of the surface of any body, whatever its position. Fifteen pounds are equivalent to the weight of the quantity of mercury that fills a tube or bottle of one inch bore, and about thirty inches long; or to the weight of *water* filling a pipe of that bore and thirty-four feet long. Accordingly, if either of these vessels, having been closed at one end, and so filled, be carefully inverted perpendicularly into a basin of fluid, the pressure of the atmosphere upon the surface of the fluid will be an equipoise to what is contained in the tube, and will support it. This constitutes the instrument called the barometer.[*]

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[*] The barometer is supported less by half an inch on the top of St. Paul's, than at the level of the Thames. On Mont Blanc, only the half column of mercury, or fifteen inches of it, is supported. In De Lussac's balloon ascent, (note to def. 27,) the mercury fell below twelve inches.

N We may judge, from the above experiments, that the whole body of the atmosphere is equal to a covering of water thirty-four feet deep; or to a covering of quicksilver of the depth of thirty inches.

1. The body of a man of ordinary size, presenting a surface of about 2000 square inches, bears a pressure (reckoning in all directions) of about fourteen tons. The arrangements of Infinite Wisdom have provided for this pressure on the human frame, the juices of the body having just such a tendency to expand as this pressure is fitted to counteract. In climbing the Andes, Baron Humboldt found that the blood burst from his lips and ears.

2. "By that admirable property of the equal distribution of fluid pressure, (L, p. 169,) not only are we enabled to sustain the 30,000 pounds' weight of atmospheric pressure, without feeling it, but that pressure may be *doubled* by immersing the body thirty-six feet under water in a diving-bell, and yet no single nerve, not even the most delicate of the millions which overspread the body, will, by reason of that pressure, experience the least perceptible excitement."—*Moseley's Mechanics.*

3. It is because the pressure of the atmosphere, like that of every other fluid, is communicated equally in all directions, that the boy's leather *sucker* carries the weighty stone on which he places it; that the common house fly * walks on the ceiling; that the snail can crawl, sustaining the burthen of its shell in any position, &c.

P The united masses of the ocean and atmosphere, are but insignificant when contrasted with the quantity of solid matter in the globe. The greatest depth of the sea is estimated at five miles; (*a*) and if that which is now the "dry land," were levelled and distributed, so as to form its bed, its uniform depth would be very inconsiderable. We have seen (M 5, p. 170) that the mass of the atmosphere, if sufficiently condensed, would be equal in bulk to an ocean of water of about thirty-four feet depth; so that, regarding these depths as to be represented, unitedly, on an ordinary twelve-inch globe, they would be but as the film of moisture produced by breathing on it, when first brought out of a cold room; or at most, as the coating of varnish which always covers it.

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* Those most skilful in microscopic observations, have great difficulty in detecting the *sucker* in the fly's foot. The Acarus frequently found in great numbers infesting the common blue beetle, and so much in need of the means of firm adhesion, whilst the beetle "wheels his drony flight," is provided, on each foot, with a beautiful transparent sucker, attached by a fine muscular cord. A common microscope will show this with a very moderate power; and if the little animal be carefully shut in between the two glasses of the "*live box*," and very slightly compressed, it will exhibit these suckers in action. The author is not aware that this object, exquisitely illustrative as it is, is noticed in any publication on the microscope.

(*a*) The *mean* depth of the Pacific, is supposed to be about four miles; that of the Atlantic, about three miles only.

1. Yet "the addition to the sea of one fourth of the existing waters, would drown the whole of the globe, except a few chains of mountains;"(b) and were the mass, and consequently the weight or pressure of the atmosphere, increased, "the stress of wind and weather" would be ruinous to the present structure of organized matter.

2. The proportion of surface also presented by the ocean, though apparently excessive, is that which is required for the refreshment of the land. "The properties of water, with respect to heat, make one vast *watering-engine* of the atmosphere." The quantity supplied for this depends mainly on the extent of surface; and if the surface of the ocean were to suffer any considerable diminution, the continents, as they at present exist, would be robbed of their fertility.

3. Although the air over the sea generally contains more vapour than the air over land, the saltness of the waters of the ocean, amongst other benefits, restricts their tendency to evaporation. Salt water has even the power of *drying* the air, when it contains vapour in great quantity, by absorbing a part of it.

HEAT.

The term *Caloric* is employed by some philosophers, to distinguish the agency of heat from the sensation it produces, but common usage has long applied the term "heat" to both; and it is so employed by some of the best authors.

RADIATION, CONDUCTION, CONVECTION, ETC.

Q Every body that is warmer than the space around it, radiates the difference of its heat, more or less rapidly according to circumstances; and every colder body near it receives, more or less readily, a portion of the heat thus sent forth.

(b) Whewell's Bridgewater Treatise, p. 52.

R The power of the warmer body to give forth its heat, will depend on its surface, as well as on the nature of its substance.

1. Thus, of two vessels of heated water, that will retain its heat much the longer which has a polished surface.

2. Our bodies are constantly radiating heat into the colder air; and the clothing that is warmest, is so only in consequence of its most effectually resisting the escape of heat.

The snowy covering of winter effectually protects the earth, and its germs of vegetation, from the severity of the atmosphere; the under surface of snow generally retaining the temperature of 32°, (the freezing point merely,) whatever the state above.

3. As soon as the beams of the setting sun have ceased to affect the earth's surface, being now the warmer body, it begins to radiate its heat freely into space; until, becoming colder than the air immediately around it, it robs this air of its heat, and together with its heat, robs it of the power of retaining its moisture: (see Latent Heat.) This is deposited in the well known form of *dew*. The more the nature of the surface, as to vegetation, colour, &c., is adapted to radiate, the colder it of course becomes. Hence, we find some patches of land bedewed whilst others are dry.*

S The power of the cooler body to receive heat, will also much depend upon its surface and colour.

1. If the surface of a body be such as to *reflect* much heat, it will, of course, *absorb* the less of it.

"Surfaces receive heat by radiation, nearly with the same degree of facility as they give it off. * * * A surface covered with lamp-black, for instance, receives, in a given time, eight or nine times as much heat by radiation as a polished tin surface."—*Dr. Prout.*

T "The earth, like all solid bodies,† transmits into its interior, the impressions of heat which it receives at the surface, and throws off the superfluous heat from its surface into the surrounding space. These processes are called *radiation* and *conduction*."

"By the laws of conduction, the daily impressions of heat which the earth receives, follow each other into the interior of its mass, like the waves which start from the edge of a canal. * * * And as *all* parts of the surface throw off heat by radiation; in the Polar regions, where the surface receives little in return from the sun, a constant waste is produced. There is thus, from the Polar part, a perpetual dispersion of heat into the surrounding space, which is supplied by a perpetual internal flow from the equator* toward each pole."—*Whewell.*

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* If the night too, prove a cloudy one, the clouds themselves radiate, as well as reflect back this radiated heat; and the temperature of the earth, and consequently of the air at its surface, being thus kept up, no dew is deposited.

† "All the reasons we can collect, appear to be in favour of the earth's being a solid mass, considerably denser than any known rock."—*Whewell's Bridgewater Treatise*, p. 50.

V When heat is applied to a fluid, otherwise than at its upper surface, there is an immediate intestine motion communicated to its parts; those nearest the source of heat, becoming more buoyant by increase of their bulk, and ascending, whilst the cooler portions descend to supply their place. Heat is diffused through fluids in this way only, and it is termed *convection, i. e.*, the *carrying* process.

1. Count Rumford caused water to boil at its surface, whilst a cake of ice remained at the bottom of the vessel containing it; because the heated water could not descend.
2. Into a good sized phial, nearly filled with cold water, put a small quantity of amber dust, (to be obtained at the chemist's,) or anything which may be barely suspended in water. If the phial be now placed in a tumbler half filled with hot water, currents will be established, which the floating dust will render visible; the water nearest the heat ascending, and a cooler column descending in the middle, until the whole becomes of uniform temperature. When this is the case, the currents may be beautifully reversed by placing the bottle in a tumbler of cold water. A hot and cold hand will answer the purpose, but the currents will not be so active as in the other case.
3. The air of a well warmed apartment is continually flowing out at the top of the door, and flowing in at the bottom of it. This may be seen very plainly, by opening the door a few inches and holding a lighted candle alternately near the top and near the bottom; the flame in the former instance floating outward, and in the latter, toward the inside.
4. In the same way, the heated air of the Torrid Zone ascends, whilst currents of air flow from the higher and colder latitudes of the north and south, to take its place.—See *Trade Winds*, (*Index.*)

W By the same process heat is communicated *by* a fluid *to* a colder body *above* it; the portions near the surface, parting with their heat, will continually descend to make way for the warmer and lighter portions below, until the temperature of the body above is rendered equal to that of the fluid.

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* *i. e.*, from the equatorial *regions*, where there is more heat derived from the sun.

1. If wind from a cold region come over a surface of land, that surface becomes cold, and remains so; the wind therefore cannot get its keenness in any degree abated; but it will be seen, from what is advanced above, that if the same wind blow over a deep and extended sea, it may not only become mitigated, but even become warm in its progress.

"When a warm wind blows over land, it heats the surface, which must therefore cease to abate the fervour of the wind. But the same wind blowing over water, agitates it, brings up the colder water from below, and thus is continually losing some part of its own heat."—*Dr. Robertson's "America."*

X This accounts for the moderated climates of insular situations.

Y Bodies perfectly transparent are nearly unaffected by solar heat, and even very little affected by terrestrial heat if it be intense. Thus window-glass, perfectly clean, intercepts no heat, remaining cool whilst the sun's rays pass through it with all their power. One cause of the low temperature of the atmosphere in the upper regions, is its purity and consequent transparency. It is for the most part, the *sluggishness* of heat, after it has been treasured by the earth, that gives warmth to the air, and produces its currents, (as described in V, p. 174, and its notes.)

LATENT HEAT.

B That portion of heat which is essential, and barely so, to the existence of a body as liquid or aeriform, is called *latent* (that is, *concealed* or *insensible*) heat, because it is not perceptible to the touch, or by the most delicate instruments. Bodies, solid as well as fluid, have various powers of absorbing and concealing heat, and these powers are termed their *capacities* for heat.

1. In the *match-syringe*, (an instrument consisting simply of a small tube closed at one end, and an exactly fitted moveable plug,) a portion of the air of the coldest day may be squeezed so as to yield a spark, and ignite a portion of tinder placed under the plug.

2. It is the water, however low its temperature, and not the lime,

which gives out the large quantity of sensible heat, observed whilst it is becoming solid in the well known process of *slaking* lime.

3. In the act of freezing, water gives out heat; this renders our frosty days frequently much more comfortable than the time of thawing; for, on the contrary, during the latter process, the ice or snow, in becoming fluid, robs the air of the heat required for its fluidity.

4. If equal weights of lead, chalk, and milk, be placed in an oven to acquire its temperature, the chalk will require more time than the lead, and less time than the milk, for this purpose. This is owing to the difference of the *capacities* of these three bodies for heat; and to prove that the chalk, and especially the milk, have absorbed, and rendered latent, a portion of heat which the lead has not, if each be put into an equal quantity of cold water, the chalk will raise the temperature of its water more than the lead, and less than the milk.

5. If a pan of ice or snow be placed before the fire, a thermometer plunged into it will show that the temperature is not raised above 32°, (the freezing point,) until the whole is melted; all the heat communicated by the fire, however brisk, being absorbed and *hidden* by the water, as necessary to its fluid state. For a similar reason, we cannot, in the ordinary way, raise the temperature of water above 212°, (the boiling point,) all additional heat being carried off in the latent state by the steam, as necessary to its gaseous condition.

6. The same portion of latent heat is contained in a quantity of vapour slowly escaped from the surface of a lake, as in the same quantity of vapour from a boiling cauldron.

C If it were not that in thawing, each particle of the frozen body in succession requires its portion of heat, its liquefaction would be instantaneous. "At the first touch of warmth, all the snow which lies on the roofs of our houses would descend like a water-spout into the streets; all that which rests on the ground would rush like an inundation into the water courses."—*Whewell's Bridgewater Treatise*, p. 92.

If the conversion of the fluid into the aeriform state, were not, for the same reason, so gradual, the application of cold water to fire would cause a sudden and terrible explosion.

1. On the lofty mountain top, (or in the partial vacuum obtained by an air-pump,) little heat is required to turn water into steam, and all additional heat becomes latent; hence, in such situations, provisions cannot be cooked by boiling.

D When a body of air is raised by being heated, (see 4 of V, p. 174,) it further expands in volume as it becomes released from the pressure of the air formerly above it. The heat of its high temperature thus becomes latent in this its expanded state; and, although it may have been melting sealing-wax at the earth's surface, it has not now the power of keeping its moisture invisible, (see Evaporation,) or even of dissolving snow. Hence, it may deposit a cloud, and make its way along the frozen summits of mountains without changing their condition. (*a*)

1. We may judge from the above, that this body of air, when it again reaches the earth's surface, will not necessarily be cold; for, being again compressed by the weight of the atmosphere through which it has descended, a portion of its latent heat is again set free, and it may be nearly as *warm* as before its first rising.

2. When, at the Cape of Good Hope, the wind blows from the south-east, the Table Mountain has its summit enveloped in a remarkably dense and beautiful cloud, which appears to be rolling over the mountain top, but never descends. "The reason of the phenomenon is this— * * * The air constituting the wind from the south-east, having passed over the vast southern ocean, comes charged with as much invisible moisture as its temperature can sustain. In rising up the side of the mountain, it is rising in the atmosphere, and is therefore gradually escaping from a part of the pressure lately borne; and on attaining the summit, it has dilated so much, and has consequently become so much colder, that it lets go part of its moisture. This then appears as the cloud just described; but it no sooner falls over the edge of the mountain, and again descends in the atmosphere to where it is pressed, and condensed and heated* as before, than it is re-dissolved and disappears; the magnificent apparition dwelling only on the mountain top."—*Dr. Arnott's Elements of Physics.*

Remarkable deviations in the workings of general laws, with respect to the Atmosphere and to Water.

1. *With respect to the Atmosphere.* Philosophers have ascertained that the atmosphere, under ordinary circumstances, is thus composed:—

(If we suppose any given quantity of air to be divided into 1000 equal parts,)

Oxygen, 210.
Azote or Nitrogen, 775.
Aqueous Vapour, $14\frac{2}{10}$.
Carbonic Acid, $\frac{8}{10}$.

(*a*) This removes a difficulty which the pupil may probably have found, in conceiving how perpetual snow should exist even in tropical climates.

* That is, the heat which had become latent in its expanded state on the mountain top, becoming again disengaged by pressure, and raising its temperature.

But that by a wonderful and admirable exception to a general law, which would cause them to act upon each other and change their properties, these constituents *do not* become combined, *i. e.*, they do not form a state of chemical union, but are *simply*(*a*) *diffused through* each other; and that this fact of the simple mixture of these elements of our "vital air" in these proportions, "is the cause constantly operating," to prevent that "unequal distribution of them, which would speedily prove fatal to organic life."(*b*)

2. *With respect to Water.* We have learned that bodies, generally, are expanded by heat, and that they are, consequently, rendered dense in proportion as their heat is taken away. In the case of *Ice*, (the solidification of water,) the operation of this law would have caused it, as soon as formed, to sink in our rivers, and thus form layers at the bottom, until the whole became a congealed mass which no summer heat could liquefy.

Mercury, oils, and other liquids, obey this law and continue to contract; but water contracts no longer than until reduced to the temperature of 40°; it then begins to expand, and its coldest portions, thus becoming lighter than the rest, float at its top, to become ice and to protect the rest of the water and its inhabitants. "In order therefore, that *water might not be frozen*, and that *air might not become irrespirable*, laws must be infringed—and THEY ARE INFRINGED, infringed too, precisely where their infringement, both in kind and degree, is indispensably necessary to organic existence."—*Dr. Prout.*

EVAPORATION, CONDENSATION, CLOUDS, RAIN, ETC.

F We use the word Steam when referring to the vapour of *hot* water; but water at all temperatures, even in the

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(*a*) Many substances, common salt for instance, *deliquesce*, *i. e.*, become fluid by mixture with the vapour they entice from the atmosphere. Sulphuric acid (*vitriol*) will double its weight in this way.

(*b*) The two principal gases of the air, *viz.*, nitrogen and oxygen, in certain chemical union, form that virulent poison, nitric acid (*aqua fortis.*)

condition of snow or ice, is constantly supplying vapour to the atmosphere. Vapour, whether produced from fluid of a high or a low temperature, is invisible. Clouds, fogs, or the smoke-like wreaths which are seen issuing from the tea-kettle, are not vapour, but vapour condensed into "fine watery powder." The existence of a portion of vapour in the atmosphere, seems necessary to healthy breathing. The leaves of plants are furnished with the means of absorbing it for their continual nourishment; and some plants can exist, and even grow, in this way, independently of the soil.

C We have just seen, (p. 178,) that the water thus existing invisibly in air, is not chemically united with it. Vapour "may be considered as flowing (upward) among the particles of air, *like a stream of water among pebbles*."* The particles of the air thus as it were, ***stand in the way*** of the rising of vapour, and it would seem that, accordingly, evaporation is a process regulated in some degree by the density of the air, or the quantity of it in any given space. "If a vacuum be formed, evaporation takes place suddenly." On our hottest days, and in our clearest state of weather, the air is most impregnated with vapour. It is most abundant in the atmosphere when most needed.

1. The atmosphere of vapour existing thus *in* the atmosphere of dry air, presses with its *own* independent portion of that which, as a whole, supports the thirty inches of mercury in the barometer, (M 5.) But, by a beautiful provision, the temperature and elasticity of a portion of this vapour at any given height, follow a different law from that which, independently, the *dry* atmosphere follows; and thus the vapour column has the property of remaining able to support *condensations* in the regions of clouds above, without so pressing upon the earth's surface as to preclude evaporation. "If water exist there it will rise by evaporation, the surface *feeling insufficient tension*."—*Whewell's Bridgewater Treatise*, p. 103.

2. The quantity of vapour present in the air depends upon its temperature. If the air be *saturated* with moisture, that is, if it have quite as much as it is capable of holding in a state of invisibility, whilst only of its present *warmth*, it is evident that any reduction of its heat must cause it to let fall some of this moisture. This is seen when a glass of cold water, or any thing of low temperature, is first brought into a warm room; or by the streaming on the panes of the windows of any place of assembly.

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* Whewell's Hist. of the Inductive Sciences, Vol. II. p. 511.

H We have seen, (D, p. 176,) that if air become heated and thus expand and ascend, its further expansion, as it escapes from the pressure of what it leaves below it, reduces its temperature, by requiring and absorbing its heat and rendering it *latent;* it must then, if before rising it were *saturated,* almost immediately deposit a portion of its vapour; so that, if the air in contact with the earth's surface *were permitted to take up* as much moisture as its temperature there could enable it to hold, directly it began to rise it must deposit a mist; and we should live (if indeed we could so exist) under a constant fog, through which the rays of the sun could not penetrate. The great Creator and Ordainer has provided against this.

1. "The air every where incumbent on the earth's surface, must always be *under* the point of saturation."—*Prout.*

Dr. Prout shows, (Bridgewater Treatise, p. 298,) that in consequence of the benevolent arrangement referred to above, the air at the equator, where the average temperature is 80°, is allowed to hold only such a portion of invisible vapour as is due to the temperature of 61°;* and thus that it *can* rise by expansion without thus depositing its aqueous vapour, until it reaches, or rather gets above, the region of this temperature of 61°; viz., 6000 or 7000 feet. "At this height, its vapour will be condensed and a cloud will be formed; which may either be precipitated on the spot from which its constituent vapour had risen, or may be transported by the currents of the atmosphere, similarly to refresh a distant country; or may be again dissolved in the air: while under all these contingencies, the whole of the lower portion of the atmosphere is exempt from mist, and continues perfectly transparent. These operations are unceasing."

* * * * *

2. The very lofty summits of mountains, are much above the re-

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* Our young readers will now understand what is meant by "*the dew point.*" It is evident that if the earth's surface at the equator, under these circumstances, be cooled down at night by radiation (Q, p. 172) *below* these 61°, it will rob this air, so in contact with it, of a portion of the water it contains, by robbing it of a portion of these 61° of heat, and consequently of its power of keeping *all* its vapour. In our variable climate, the average temperature is 49½°, and on the average, the atmosphere in contact with the earth's surface with us, is possessed of no more vapour than it could hold at a temperature of 44⅓°; this therefore is our average "*dew point.*" In general, in any state of the atmosphere, "there is a certain temperature lower than that of the atmosphere, to which, if we depress bodies, water forms on them in fine drops like dew; this temperature is hence called the *dew point.*"—*Whewell's Inductive Sciences,* Vol. II. p. 510.

gions of the clouds. Travellers who have ascended such eminences, have often contemplated the thunder-storm raging far beneath them. The Peak of Teneriffe has the clouds floating so far below it, that sailors at a great distance frequently mistake them for white cliffs, or the crests of billows at its base.

3. The dense fog which continues on the sea of the Polar regions, for weeks after the sun has begun his long visit, (see note to quest. 3, p. 134,) is occasioned by the air from the land, which, being now warmer, and consequently containing much invisible vapour, on coming into contact with the air of the colder sea, has a portion of this vapour condensed by it. The mists and fogs of *our* early summer, arise from like causes. But a similar fog, for several weeks, clothes the sea surface at the *end* of the long sunny period *there*; and this, on the contrary, is occasioned by the air on the warmer sea being, in its turn, cooled and caused to deposit *its* moisture by the air which flows down from the more rapidly chilling land. The mists and fogs prevalent in low situations in *our* autumnal season, arise from a similar cause.

LIGHT.

K "Light is an emanation, or something which proceeds from bodies, and by means of which we are enabled to see them by the eye."—*Brewster's Optics.*

1. "Some philosophers refer the origin of all luminous phenomena to the sun, whose beams are supposed to penetrate, and combine with, the different forms of terrestrial matter; but we learn from scripture that light pre-existed before the sun, and that its subsequent condensation in his orb was a particular act of Almighty power. The phosphorescence of minerals, buried since the origin of things in the bowels of the earth, coincides strictly with the Mosaic account of the creation."—*Dr. Ure's Chem. Dict.*

2. "No truth in philosophy seems to be now more clearly ascertained, than that light has a distinct existence, separate and independent of the sun. This is a striking confirmation of the Mosaic record; for that expressly distinguishes the existence and operation of light from the solar action upon it. * * * An interval of three days is placed between the luminous creation, and the appearance and position of the sun and moon."—*Sharon Turner's Sacred History of the World*, Vol. I. p. 92.

"This grand physical truth could not have originated 4000 years ago from any *human* mind; it is in opposition to all ordinary sensation."—*Ibid.* p. 103.

L The circumstances under which we view luminous objects, very much influence our estimation of their brightness and size. We admire the brilliance of the full moon, yet the best computations find it to be only a *three hundred thousandth part* of the brilliance of the meridian sun. The dullest white cloud of day, if its light could be reserved and it could be suddenly introduced at night by the side of the moon, would outshine it. This may be imagined as we contrast these objects in the day-time.

1. Uranus, the planet most distant from our sun, receives, on an equal portion of its surface, only a two thousandth part of the light which falls on Mercury, the planet nearest to that luminary; or, about a three hundred and fiftieth of that which a similar portion of our own surface receives; but this is equal, nearly, to the light of 900 full moons.

2. When the moon is *young*, the darker portion of her disk (see B on p. 15) appears like a part of a smaller body; and it is difficult to persuade one's self that the extremities of her bright cusps or *horns* are really portions of an unbroken outline.

3. It is equally hard to believe, that the dilated appearance of the moon at her rising or setting, is owing to the warping of the judgment whilst we compare her with the terrestrial objects which intervene. If a large sheet of stiff paper (as of music paper) be rolled up, and carefully narrowed, until, on looking through it as a tube, we can exactly take in the circumference of the horizontal moon, it will be found, if tied up securely, to be sufficient only for taking in her circumference when she is at her greatest altitude. Astronomical measurement, indeed, can detect a real increase in her disk when considerably elevated, as she is then nearer to us.

REFLECTION AND ABSORPTION OF LIGHT.

M "*Self-luminous bodies*, such as stars, flames of all kinds, and bodies which shine by being heated or rubbed, are those which possess in themselves the property of discharging light. *Non-luminous bodies*, are those which have not the power of discharging light of themselves, but which throw back the light which falls upon them from self-luminous bodies."

1. "When a lighted candle is brought into a room, the form of the flame is seen by the light which proceeds from the flame itself; but the objects in the room are seen by the light which they receive from the candle, and again throw back, (or reflect,) whilst other objects, on which the light of the candle does not fall, receive light from the white ceiling and walls, and thus become visible."—*Sir D. Brewster's Optics*, p. 1, 2.

2. Thus the sun and fixed stars are self-luminous; but the moon and planets owe their appearance alone to the light thrown upon them from the sun, and reflected in all directions from their roughened surfaces.

3. The surface of the moon is evidently very mountainous, and the most skilful observers, by means of the best telescopes, have detected remarkable protuberances in Venus. But the mountainous character of the surfaces of all the planets has been inferred from this, that they *scatter* the sun-beams they receive, and thus appear *generally* illuminated. A polished ball of silver hung up in a room having black walls and in which there is only one candle, like the convex mirror used in drawing rooms, will reflect, to any one spectator, only one minute *figure* of the candle flame, and have the rest of its surface dark.

4. If it were not for the reflecting particles abounding in our atmosphere, even the sun would fail to afford us daylight, and the heavens would be black except in that small portion in which his figure appears. The blessing of Twilight, so important especially in some regions of our globe, would be altogether unknown. At the summit of Mont Blanc, in consequence of the deficiency of atmosphere above for reflecting the rays of light, the sky appeared to Mons. Saussure as black as ebony.

N The reflection (or *bending back*) of light takes place, in some degree, from every surface upon which it falls, or we should not see that surface; but even from those best polished, and consequently reflecting most, *all* the light that falls is not reflected. Some light always *enters* the substance, and, if not transmitted through it is lost within it. The general law of the reflection of light is that *the course of a beam in returning* from any point of a surface at which it has fallen, *makes the same angle with the surface that it did in falling upon it.*

1. "One of the most curious properties of bodies in their action upon light, is their power of absorbing it. * * * Even the most transparent bodies in nature, air and water, when in sufficient thickness, are capable of absorbing a great quantity of light. On the summits of the highest mountains, where their light has to pass through a much less extent of air, a much greater number of stars is visible to the eye than in the plains below."—*Brewster's Optics*, p. 137.

2. "With respect to the propagation of light through water, it has been calculated, that not a *tenth* part of the incident light can advance *five fathoms* (thirty feet) downward; and that, even of vertical rays, one *half* is lost in the *first seventeen feet*. * * * The depths of the ocean must be always in perpetual darkness."—*Dr. Prout's Bridgewater Treatise*, p. 256.

3. "A vertical ray of light, in its passage through the clearest *air*, has been calculated to lose at least a fifth part of its intensity before it reaches the earth's surface. From this cause, and from the actual condition of the atmosphere, it has been estimated that, under the most favourable circumstances, of 1000 rays emanating from the sun, only 378, at a medium, can penetrate to the surface of the earth at the equator; 228 in the latitude of 45°, (half way between the equa-

tor and the pole,) and 110 only at the poles; while in cloudy weather, the several proportions are a great deal less."—*Ibid.* p. 237.

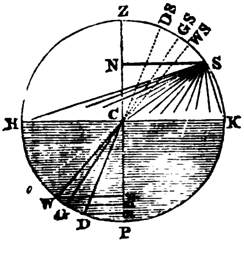
These statements are to be considered only as approximations to the truth; it is not known whether they are equally applicable to the accompanying rays of heat.

4. Sir John Herschel conjectures, from the rare appearance and want of permanence of the spots seen on Venus, and *suspected* on Mercury, that we do not see, as in the moon, their real surfaces, but only the intense light which is reflected from their atmospheres, much loaded with clouds, and from the glare of which their surfaces are thus protected.

5. The atmosphere of the moon "was beautifully seen under the most delicate of circumstances, during the annular eclipse of May 1836, when, immediately before the completion of the ring, just before the rims of the two bodies osculated, the light of the sun shot through the moon's atmosphere, mollified into lovely twilight."—*Professor Nichol's Phenomena of the Solar System*, p. 162.

REFRACTION OF LIGHT.

P It may be stated, generally, that when a transparent substance is of uniform density, that is to say, when its component particles are equally and uniformly distributed, the light which enters it passes through it in an undeviating line. When its density varies, the course of the ray varies with it. So, also, if the course of light lie through several substances of different densities, or different refractive powers; as through air and water, or through water and glass, or through glass into water and ultimately into air; in every instance, that inclination of the course of a ray which is occasioned by *increased* refraction, is *towards a perpendicular to the point of the surface at which it enters;* as though the force of its movement were gradually hindered, and thus its way *perverted*, like that of a stone flung forcibly sideways into a pool.



Let the accompanying figure represent the vertical section of a glass globe exactly half-filled with a transparent substance, as water. Then will C be the centre of this globe.

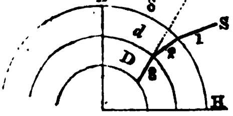
Let us now suppose a spark to have fallen upon the globe at S. Rays from this object will fall over the whole surface of the water from H to K; but for the sake of measuring the direction of its course, we will neglect all but that which falls on the central point, C.

This ray, which would proceed in its straight forward path to (*o*) if the globe were quite empty, will now, on entering the water, be diverted to W (a point nearer than *o* to the perpendicular Z N P drawn through C.) If the lower half of the globe, instead of being filled with water, were of *solid glass*, this ray would proceed to G; and if we could have it of diamond, it would proceed to D. Hence, the eye must be placed at W, at G, or at D, to perceive S by means of this beam, according to the "medium" through which the beam comes; and, in looking along W C, or G C, or D C, it would see it more or less *elevated* by refraction; *i. e.*, as if at W S, or G S, or D S.

Q The angle S C Z, which the ray makes with the perpendicular Z N C P in falling upon the surface at C, is measured by its *sine* S N (K, p. 16.) So also, the lessened angle W C P, made by the path of the ray when refracted in its passage onward, is measured by W n, *its* sine. The ratio between these two sines S N and W n, found by dividing one of them by the other, (see R on page 11,) is called the *Index of Refraction.*

Thus, suppose the length S N to be 60 inches, W n (in water) will be 45 inches; G n (in glass) will be 40; D n (in diamond) will be 24 only. Hence, the index of refraction of water is 60 divided by 45 or 1⅓; of glass 60 ÷ 40 or 1½; of diamond 60 ÷ 24 or 2½.

R We have learned, (M 3, p. 170,) that the density of any portion of the fluid atmosphere in which we live, and through which we see the stars, &c., depends mainly upon the pressure of the other portion above. Hence, its density is comparatively little in the higher regions, and so its power of *refracting* rays of light.



Thus the course of a ray proceeding from a heavenly body to impress our sight, is necessarily bent more and more in its course until it reaches us. If we take δ d D for portions of our atmosphere of differing height, (and therefore of differing density,) then 1, 2, 3, may be regarded as portions of that ray's course; and the impression with respect to the elevation of S above H (the horizon) will be that it is at EL, or nearer to the zenith than it really is.

1. The displacement by refraction, like that of parallax, (G on p. 18,)

is greater as the object is nearer the horizon; but parallax *depresses*, whilst refraction *elevates*, and hence, the *difference* between these two effects is allowed for in nautical observations.

DECOMPOSITION OF LIGHT BY REFRACTION AND ABSORPTION.

S The *Newtonian* theory of light supposes it to consist of "material particles emitted by luminous bodies and moving through space" with a velocity of 192,000 miles per second.

In the *Undulatory* theory,(a) "an exceedingly thin and elastic medium called *ether* is supposed to fill all space, and to occupy the intervals between the particles of material bodies, * * * and when any vibrations or undulations are propagated through this *ether* and reach the retina (b) of the eye, they excite the sensation of light." *Dr. Brewster's Optics, Cab. Cyclop.*

T All the varied beauties of colour result from what, on either of these hypotheses, is called the *decomposition* of light. Each beam of common light consists of at least three parts, the *red*, the *yellow*, and the *blue*. It is only when a body reflects to the eye all these parts of light, without disuniting them, that it appears white; or when, on the contrary, it absorbs them all, that it appears black. The blue, and yellow, and red, and the various hues resulting from the combinations of these, are all partial reflections of white light, of which the other portions are either being absorbed or scattered in other directions by the bodies presenting them.

V When a beam of light is made to pass through the very oblique sides of a glass prism, (as through the cut glass ornaments of a chandelier,) it is decomposed and *dispersed*; that is, it issues from it beautifully divided into its constituents, in a lengthened figure which is called the *spectrum*.

(a) First suggested about the same period as Newton's by Huyghens, a Dutch mathematician.

(b) The web of nerves behind the eye.

1. The colours of the spectrum, and the compounds formed V
where they encroach on one another, are *seven*, and their order I
may be recollected by the word *vibgyor*. If seven powders, each B
distinctly having the colour of a ray of the spectrum, be mixed G
in the proportion of the spaces which their colours occupy in the Y
spectrum, they will form a *white* powder; but the white will be O
dingy, because the separate colours cannot be accurately imitated. R

2. In note C to H on p. 15, we referred to the decomposition of light which takes place as it passes through those portions of an uncorrected lens which are nearest to the circumference, and therefore receive rays most obliquely. The beautiful colours of sun-set or sunrise, are caused by the decomposition of light coming to us in so oblique a direction, through so large a portion of the lower atmosphere and the exhalations it contains.

3. The rainbow is produced by the decomposition of the sunbeams, cast from behind the observer into those spherical drops of the rain, falling at a distance in front of him, which are so situated as to reflect to him, in a refracted and dispersed state, the light they receive. Only one of the coloured rays out of the seven that are at any instant proceeding from a drop of rain thus situated, can have its course so directed as to reach the eye of the spectator; and thus a second person may be near receiving the red ray from a drop which, at the instant, is supplying the blue one to his neighbour. Hence it is often said, no two persons can see the same rainbow.

4. The pupil cannot have failed to notice the difference of colour of the more brilliant stars; the contrast, for instance, presented by Sirius and Aldebaran, by Vega and Arcturus or Capella. Several of those most wonderful objects, the telescopic double stars, have their individuals thus contrasted; a red and a green one for instance, or a yellow and a blue. If (as in all probability is the fact) we imagine such to be suns, jointly serving as luminaries to systems of planets revolving amidst their beams, we may conceive of the alternate union, separation, and absence of their beams, from the hemispheres of those rotating planets, as yielding, alternately, a *white* day or a green one, or a red or yellow one, and darkness.

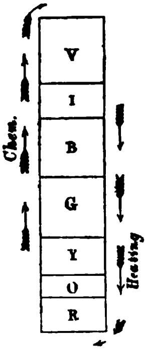
5. Rub a little table salt into a small skein of lamp cotton, and place it in a cup with a little spirit of wine. The light produced by inflaming this has no *red* in it, and cannot, therefore, afford any by reflection. Accordingly, the rose or peony appears by this light of lead colour; and the more healthful and florid an individual is, the more ghastly he will appear.

THE SPECTRUM.

W The "*Spectrum*," or exhibition of the divided beam, (see V p. 186,) is found to consist of two invisible parts, besides the three colours and their compounds.

These invisible parts are:—The *Chemical* rays, and the *Calorific* or heating rays. The chemical rays are known by their effects on vegetable colour and on some minerals:

The heating rays are indispensable to the existence of the animal and vegetable creation.



According to Sir David Brewster's analysis, each of the three colours (blue, yellow, and red,) pervades the *whole* of the spectrum; but presents itself to the eye as a *colour*, only where it is not so mixed with the other two as to constitute white with them. Each of the two invisible parts of a beam, (referred to above,) likewise pervades the whole spectrum; but the heating ray increases in intensity towards R, (the red end,) where it overlaps; the chemical ray being similarly diffused in the contrary direction and overlapping at V, (the blue or violet end).

1. By placing in the several coloured divisions of the spectrum, small pieces of card moistened with a solution of horn silver, (chloride of silver,) the powers of the several portions of the chemical ray belonging to the different colours, are made evident by the several greater degrees of blackness those pieces of card acquire which are nearest to B, the blue or violet end.

2. The recent application of the chemical influence of light to *Photogenic drawing*, is by means of paper washed over with the salts of silver.

3. Mrs. Somerville and some of the continental philosophers, have found that needles may be magnetised by keeping them for some time in the blue or violet end of the spectrum; but that there is no effect produced by exposing them to the red end.

4. A black substance, in absorbing all the parts of light without reflecting any of them, absorbs, with them, all the several portions of the calorific ray which belong to them, and accordingly, becomes sooner warmed than a substance of any colour. A substance of a blue colour, or one reflecting the blue part of light, reflects with the blue, only that least portion of the heating rays which belongs to that colour; and since it absorbs all the other colours, and with them their portions of the heating rays, a blue substance becomes heated almost as soon as a black one. Next to white bodies, (which absorbing scarcely any of the parts of light and heat, reflect nearly all of them,) the red, reflecting with that tint the large portion of the heating ray belonging to it, is the slowest of colours to retain warmth, and of course, the most ready to impart it by reflection: the intervening yellow, and its compounds green and orange, following their order in the absorption or reflection of heat.

× Although these invisible portions of light, viz., the chemical and the heating rays, are found with their intensities thus spread into opposite directions over the decom posed beam, yet as long as light is undecomposed, there is reason to believe that they are equally diffused throughout it; so that their influence operates, in some degree, in the common light of the dullest day.

1. Vegetation of many kinds exposed only to such light, will thrive and be green, but will be white and sickly without it.

2. Not only the heat of the direct sun-beam, but that existing in the common daylight will have an influence in deadening the fire, by consuming a portion of the oxygen of the air which is necessary to sustain it.

Y "It is by the light of the sun that the coloured juices of plants are elaborated, that the colours of bodies are changed, and that many chemical combinations and decompositions are effected."—*Brewster's Optics, Cab. Cyclop.* p. 184.

1. An English manufacturer of pigments contracted to pay a considerable sum to a continental chemist, for a discovery of that part of the process of making *French* vermilion which produced the superiority of its colour; but he had the mortification of finding that the Frenchman had nothing new to communicate, the effect being due alone to the less interrupted brightness of French *daylight*.

2. Vermilion is a chemical compound of mercury (quicksilver) and sulphuric acid, (vitriol): long continued exposure to light will reduce it to its constituents; the acid being thus separated, and the quicksilver uniting into globules.

3. The quantity and continuance of the direct beams of the sun, (and therefore of their chemical influence,) have a remarkable connexion with the colours of flowers, &c. A red flower may not be met with in a range of miles over a damp and misty district. The colours of vegetation are paler as latitudes are higher, and the beams of the sun less direct. The tropical regions are characterized by the splendour of the colours of their plants, as well as of their birds, insects, &c.

4. Professor Moseley has beautifully alluded to the hemispherical side of a peach, as exhibiting, according as the parts of its surface have received the sun-beams more or less directly, no bad miniature of the colours of vegetation in the different latitudes of our globe.

Z The heat which exists in light is subject to the same laws of reflection and refraction with those of light itself; but many substances, which freely admit the passage of the visible portion of a beam, have the power of arresting its heat; whilst on the contrary, there are bodies which entirely intercept the visible light of the beam, but freely transmit the invisible heating portion of it.

1. Three or four times more heat from the flame of a lamp, will pass through a very thick and opaque lump of quartz, (rock crystal,)

than can be made to pass, from the same source, through a very transparent plate of *alum* of one hundredth of its thickness.

2. On the contrary, rock-salt freely admits the passage of any radiant heat, whether it proceed from the sun or from lukewarm water; and glass of so black a stain as to transmit no light from the sun, will freely transmit heat from it.

3. Whiteness characterizes the polar regions. From dark surfaces, and coloured surfaces generally, the light and heat that are most obliquely cast upon them are reflected most, and therefore least absorbed. But from a white surface, on the contrary, the light and heat thus cast are *most* absorbed and *least* reflected. In this law we see a provision which renders the prevailing condition of the frigid zones extremely favourable to the absorption of the very slanting rays they receive. If, instead of intensity of colour, whiteness had prevailed in the *torrid* zones, the reflection of light and heat would have rendered them quite uninhabitable.

[B] The chemical and calorific portions of the solar ray, although known to *us* only by other sensations than those of sight, may be *visible* to the eyes of many of the inferior animals, since many of them evidently possess capabilities and sensations which we do not possess.

"We are altogether ignorant of the perceptions which direct the carrier pigeon to his home, and the vulture to his prey before he himself is visible even as a speck in the heavens. * * * So likewise, beings may exist on earth, in the air, or in the waters, which hear sounds our ears are incapable of hearing, and which see rays of light and heat, of which we are unconscious."—*Mrs. Somerville's Connexion of Physical Sciences*, p. 244.

⁂ *The Author has devoted considerable space to notices of the different states of the matter existing on our planet, and the phenomena arising from the action of light and heat upon them, because he has generally found an inclination to consider such things in young persons who are learning the "Use of the Globes;" and because, however cursory and deficient, such notices may lead to a habit of investigation.*

The pupil who may have attentively read over the foregoing pages, is certainly the better prepared to conceive that the glare and heat which it is often said must be on the surfaces of Mercury and Venus, the dreariness of the unattended planet

Mars, the coldness and dulness of Jupiter, Saturn, and Uranus, even should they be the abodes of beings somewhat like ourselves, are not conditions necessarily resulting from greater or less remoteness from the sun.

C Philosophers, at present, more generally favour the Huyghenian or Undulatory hypothesis of light, as apparently according more fully with recent experiments and disclosures; (*c*) but whichever of them be adopted, whether we consider light as matter traversing space, or as the mere agitation of matter, the rate of its progress in the one case, or of its propagation in the other, is almost inconceivably great.

1. We learn (S p. 186,) that light, if material, travels at the rate (*d*) of 192,000 miles per second. We can form our idea of this more readily, by considering that it is equal to the rapidity of a body which could travel nearly seven times around our earth, between the two throbs of a healthy pulse.

2. "Before we can look at a single letter of a book, so as to know the form of it, the light by which it was revealed to us, if the eastern light of the morning, will be as far away as the atmosphere over America." *Readings in Science*, p. 47.

3. Light, however, takes eight minutes to reach us from the sun, so that it is often said, if he were suddenly annihilated we might continue to behold him for that length of time. From Uranus or Herschel, (our sun's most distant planet,) light does not arrive in less than between two and three hours, so that we never see that planet in its true place. It has been remarked, in consideration of the distance of the fixed stars, that some of them, which may have been for ages "put out," may be still appearing, the last rays that left them not having yet reached our eyes; whilst the first beams of others not having arrived, we are not yet apprized of their existence.

4. Sir J. F. W. Herschel's table of the data of the Undulatory theory of light states the number of undulations of ether requisite to produce the red ray to be 458 millions of millions per second, and those to produce the violet, 727 millions of millions per second!

(*c*) "Still it is by no means impossible that the Newtonian theory of light, if cultivated with equal diligence with the Huyghenian, might lead to an equally plausible explanation of phenomena now considered as beyond its reach." *Sir J. F. W. Herschel's Discourse*, p. 262.

(*d*) A most curious and interesting application of the rate at which light is known to travel, is given under the head of "Double Stars." For the discovery of the velocity of light, see "Jupiter's Satellites."

SHADOWS.

D The shadow of a body is its interception of the rays of any luminary. The shadow (properly the space shadowed) is consequently, proportionate to the relative sizes of the luminary and the obstructing body.

If there were a planet of the same dimensions as the sun, the form of its shadowed space would be a cylinder: if there were a planet larger than the sun, the shadow cast by such a planet would diverge in space. But, such is the bulk of the sun, the shadow cast by each of the primary planets, is a cone converging to a point far short of the distance of any other planet than one of its own satellites.

1. A mere shadow is invisible: in common conversation we describe a section of the true shadow or shadowed space, by the term "shadow"; and referring to the confines of light, we say the shadow is "long" or "short," according as it presents a more or less distorted outline of the body shadowing; or, as we describe it as *falling* upon a surface placed more or less obliquely within the shadowed space. Thus our own "shadows" are said to be longest on the ground when the sun is setting, and shortest when he is at his noontide height.

2. A shadow presents a faithful outline or form of the obstructing body, when it is received upon a surface which is perpendicular to the rays which are intercepted. No body except a sphere presents the same outline under all aspects. Now the outline of the shadow of the earth, as seen upon the moon when we eclipse her, is invariably circular; and this is a proof, amongst others, that our dwelling place is a globe, as the telescope shows all the other planets, as well as the great sun himself, to be.

3. It is evident that the ring of Saturn is an opaque body, since it distinctly shadows those parts of the planet's surface which lie in the same plane with certain portions of the ring's illuminated surface and the sun. It would seem that a part of the zone of Saturn thus shadowed, must be altogether out of sun-light for 15 years together; such being the period during which the upper and under surface of the ring are severally presented to the sun.

4. A satellite of Jupiter, as it passes around him during those months in which, whilst we look at him, the sun is below the horizon to our left, is seen to cast its shadow like a little ink blot towards the right upon Jupiter's left edge or eastern limb, *before* the satellite itself begins to pass over it; and this shadow, after traversing the disk of Jupiter, leaves it distinctly *before* the satellite does. The satellite then pursuing its course, is seen to our right of Jupiter, until as its path curves round away from us, it becomes obscured and disappears in the shadow of Jupiter himself; being behind him as it

regards the sun, and therefore eclipsed by Jupiter's shadow, whilst not yet behind him as it regards our own station.

The contrary of these positions of the shadows of Jupiter and his satellites, takes place after Jupiter's opposition to the sun; that is, after we, by pursuing our path around the sun, have moved into the space between him and Jupiter, and have passed on to the left; so that, in looking at Jupiter, we have the sun behind us towards our *right hand*. The shadows of Jupiter and those of his satellites are then cast towards our left, or in an eastern direction.

5. The projections of shadow from the numerous mountains on the wonderful surface of our moon, are ever changing their lengths and their outlines. When she is in opposition, or "full," her hollows are filled up with light, and her mountains are perceptible only by the greater quantity of the sun-beams they reflect from their rugged and extended surfaces. But if, for example, we examine her when a week old, or when she is a "half-moon," we see that these elevations are casting shadows short in proportion as they are near her smooth or rounded edge, where the sun is nearly vertical; whilst those near her rough edge, or where her surface is just rising into the sun-beams, are displaying very long black shadows. These shadows very perceptibly shorten and vary as they are watched during that small portion of the moon's rotation on her axis, which takes place during a few hours of one of our nights.

6. Since the luminary, the shadowing body, and the shadow, must all be in the same plane, and since the axis of the earth is in the same plane with every meridian, and the earth's magnitude is inconsiderable when compared with the sun's distance; if we place the straight edge of a board, or other similar body, duly north and south, and at such inclination to a level surface as the axis of the earth has to our horizon, this *edge* of board will be in the same plane also with all the meridians of our earth; and the shadow of it will, at any instant, cut this level, exactly as the shadow of that meridian plane which at the instant is turned towards the sun would cut it, were such meridian plane material and standing up above the earth's surface to cast a shadow upon our rational horizon. The gnomons of our horizontal sun-dials give their shadows thus.

7. The semi-diameter of the earth (4000 miles) is insignificant when contrasted with the semi-diameter of the earth's orbit, or our 95 millions of miles' distance from the sun; so that if we arrange the common terrestrial globe with its axis parallel to the earth's and its surface so that the spot which represents our station may be uppermost, the sun will shine upon the several situations depicted on its surface as it would shine upon them were this globe placed at the earth's centre; or as it is shining, at the instant, upon the several real situations which those are drawn to represent. For this purpose set the globe in the sunshine north and south by the compass (allowing for variation, and taking care that the table or floor upon which the globe rests be truly horizontal); elevate the pole to the latitude, and make the spot representing the place of residence, as London, &c., uppermost, by bringing it to the brazen meridian. The sun will now shine over the north or south pole so many degrees as are equal to his declination; and fine needles stuck perpendicularly into different

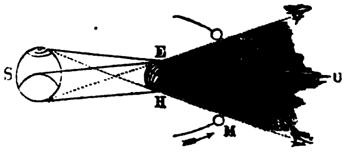
parts of the surface will project shadows, corresponding, in direction and proportionate lengths, with those which erections in the several corresponding stations on the earth's surface are projecting at the same instant.—(See "Problems for the Sunshine." Sect. III.)

8. Since the moon's distance from us is only about a four-hundredth part of our distance from the sun, with regard to his beams we may consider even her surface and our own as existing together; so that his light is cast upon us and upon her in a direction very nearly similar at any given instant. If, when she is above the horizon, we hold up a globe in the sunshine in the same direction as that in which she is appearing in the sky, (so as nearly to hide her from our view,) we shall see her phase of that time correctly represented by the globe surface. This may be better seen on one of the large white stone balls frequently placed on the pillars of gateways, if we can get on that side which is nearly opposite to the moon.

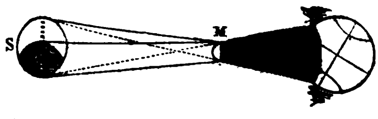
F Since we see any thing only by means of the rays it supplies to us, no part of the space totally shadowed can afford a station from which any portion of the shining body may be viewed. But around the space totally shadowed there is a diverging space, from various stations within which various portions only of the shining body may be seen. The space thus partially shadowed in various degrees is called the *penumbra*: Lat. *pene* (almost) and *umbra* (a shadow).

1. The penumbra thus surrounding the umbra or perfect shadow, may be seen by holding up a small globe in the sunshine, against a white wall or sheet of paper. When the globe is held near the wall, the outline of the umbra is large and distinct; but in proportion as the globe is held at a distance from the wall, its boundary diminishes and becomes confounded with the haziness which surrounds it. If the eye could be stationed in this hazy portion of shadow, (the penumbra,) it would see the globe hiding only a part of the sun.

2. The divergency of the penumbra, as may be readily understood from the accompanying figures, will be less the greater the distance of the sun. Thus the penumbra of Jupiter's shadow is inconsiderable, at least where it falls upon his satellites. That portion of the earth's penumbra which begins the obscuration of the moon at the times of her eclipse, is narrow, because, from her nearness, and the length of the earth's shadow, she passes through a wide part of that shadow. But the penumbra of the moon, which falls upon the earth when she eclipses the sun, is extensive, because the length of the cone of her shadow does not much exceed her distance from the earth, and sometimes even falls short of it.



Let S represent the sun,* E H the earth, and U the extremity of the earth's umbra; then the arrow and M, with the similar little circles in the curve we have drawn, will represent the moon in various portions of her orbit, during (and before and after) her eclipse by the earth. We have placed an eye at each extremity of the penumbral space, to denote where the earth is no longer obstructing a view of the sun. But it is evident that at *Pe*, only the upper portion of the sun might be seen; as also, that whilst passing the *former* portion of penumbral space, the lower part only will be visible.



Let S be the sun, with a diameter of its disk dotted into twelve digits; then M may represent the moon with her darkened hemisphere toward the earth, and her shadow with its apex a little more than reaching the earth's surface. The two eyes and the dotted lines, shew two stations on the earth just escaping a view of the eclipse of the sun; the penumbra, and the portion of the earth's surface situated within it, being lightly shewn on each side of the moon's umbra. P is a station in the penumbra, and a line drawn from it touching the moon, and reaching a digit of the sun's diameter, shews the partial eclipse of the sun at the station P, whilst it is total at U and a small portion of country surrounding it.

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* It is to be remembered, in looking at any such representation as the accompanying, of the sun and moon and earth, that it is necessarily out of all proportion. The moon, for instance, ought to be removed from the earth about thirty times the earth's diameter, and the sun should be at 400 times the moon's distance: hence, in No. 1, the earth's penumbra is drawn exceedingly large; and in No. 2, the sun is made exceedingly small to accommodate the moon's penumbra to a portion of the earth's surface.

ELECTRICITY.

G Most of those who are making use of globes have witnessed the experiments made with the usual electrifying machine, and have learned that the brilliant phenomena exhibited in them are referred by philosophers to one or other of two hypotheses, either of which will serve to explain them: some philosophers considering that there is one fluid, invisible and wonderfully subtile, pervading every surface of every body however large or minute, and probably the same with that ethereal fluid which is conceived to exist throughout the regions of space; and other philosophers supposing that there are two such fluids clothing the surfaces of bodies.

Those who favour the hypothesis of the existence of two electric fluids, conceive of them as neutralizing each other when in a state of combination; but as being disturbed and separated by various means, and each, then, individually exhibiting its peculiarity in what is called an electric state. Those who prefer the hypothesis of the existence of but one electric fluid, attribute the phenomena which bodies exhibit under excitation, to a redundancy or defect of that fluid; and a body is said to be *positively* or *negatively* electrified accordingly.

1. Bodies under the influence of the *same* state of excitation *repel* each other; whilst those affected with *contrary* states *are attracted* toward each other.

H Some bodies admit the passage of electricity with great facility, so that, when they are made to connect bodies in opposite states of excitation, equilibrium is restored by them as a means of communication and transference. Such bodies are called Conductors: of these the metals are the chief, and copper the most ready of all conductors.

Other bodies oppose the passage of electricity, or, at least, offer no facility to its passage; and of this class of non-conductors, the air, when dry, is one of the chief.

K But electric excitation is produced by an electrified body on all bodies in its vicinity: a body positively electrified producing a negative state, and one negatively electrified affecting the surfaces near it with positive electricity, even although a body perfectly non-conducting exist between them. A body thus affected by another is said to be electrified by *Induction*.

1. Thus, a cloud positively or negatively charged with electricity produces a contrary state of disturbance on the surface of the land immediately beneath it; and many persons experience a disagreeable sensation arising from this, even when there is no discharge by a thunder-storm.

2. Probably many of the inferior animals are not only variously susceptible of the influence of the electric state, but to a much greater degree than ourselves. Vegetation also, and the different substances composing the surface itself, are variously affected by the presence of an electric cloud; a thunder-storm may be tempted down or averted according as the nature of the soil is susceptible or not of this *inductive* influence.

L There are many substances on which an electric state may be produced by friction: such bodies are called *Electrics*—glass, silk, resins, and many others, are of this class. A disturbance of the electric fluid or fluids, and therefore an electric state, is produced, in the use of the common electrifying machine, by the rapid friction of a cylinder or disk of glass against silk; the glass, in this case, becoming charged with positive, and the silk with negative, electricity.

M But chemical action also, as when tartaric acid effervesces with soda or aquafortis corrodes a metal, produces an electric state. Even heat when unequally applied to metals is a means of exciting electricity; and as the earth rotates under the sun, the unequal action of heat on the different substances of which the crust of the earth is composed, probably produces electric currents; for such "electric currents have been produced by the contact of two pieces of moist clay of which one was hotter than the other." —*Connexion of the Physical Sciences*, p. 364, 4th edition.

N Any cause, whatever it be, that operates to disturb the cohesive attraction (F. on p. 167) of the particles composing a body, produces an electric disturbance in it. We may not possess the means of rendering it palpable, but every motion of our bodies, every degree of friction and pressure, even the movement of the lips in speaking, must tend to develop electricity; although, in the case of all bodies that have conducting power, the electric state is not rendered evident even by the most delicate tests, because such bodies cannot retain that state unless they are *insulated* from other bodies by means of those that are non-conducting.

VOLTAISM, OR GALVANISM.

The electricity obtained by friction differs from that derived from chemical action, (and which is called Voltaism, or Galvanism, from the names of those who first noticed it,) only in the mode of its operation.

The former is discharged by an instantaneous energy; the whole result of the excitation being at once exhausted when the means of conducting it are applied. But the agency of voltaic electricity is energetic by constant accumulation, and continues to be reproduced when that end of the machine, (or battery as it is called,) which is affected by positive electricity, is made to communicate with that end which is negative; as if a common "electric battery were feebly charged and constantly renewing its charge."*

P The identity of electrical and chemical action is completely established by the demonstrations made by voltaism. "*Bodies are held together by a definite power, which, when it ceases to discharge that office, may be thrown into the condition of an electric current,*"† and thus, during the whole of the time that the acid is employed in corroding, and thus decomposing, the molecules (B I. p. 166) of a piece of metal, these molecules, by becoming separated from the mass, are yielding a stream of electricity which may be transferred to remote parts and applied in various ways.

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* Whewell's Inductive Sciences, Vol. III., p. 73.

† Ibid. p. 169.

Z—*a*—C Z—*a*—C Z—*a*—C Z—*a*—C

Let Z (to the left) represent a plate of zinc, (*a*) a portion of diluted sulphuric acid, CZ a similar plate of copper attached to a second similar plate of zinc, (*a*) a second portion of acid, &c.

The metal usually employed for the production of voltaic electricity is zinc, as that metal affords an abundance of it when exposed to the action of very dilute sulphuric acid. The zinc (see the extreme left above) becomes negative whilst thus parting with its electricity to the acid; and the acid, by corroding it, thus acquires positive electricity.

Copper, being but slowly corroded by this acid, is employed in a piece of similar extent of surface, (see CZ above,) to convey this positive state of the acid to another adjoining similar plate of zinc, which second plate of zinc passes it on to *its* neighbouring second portion of acid, *in addition to what that acid is compelling it to yield of its own.* This second portion of acid having, (so to speak,) an accumulation of electricity, again parts with it to a second similar plate of copper; and the third zinc, in contact with this conducting plate of copper, is thus provided with a still larger augmentation of electricity, to supply, in addition to its own, to its own corroding third portion of acid, and so on.

Hence, the pupil may see that the copper, to the extreme right, is highly charged in proportion to the number of corrosions intervening between it and the first zinc. A wire is made to connect this copper with the first zinc, and thus the circuit is completed.

If one hand be moistened and applied to C, whilst the other hand is in connection with Z, we shall feel a shock as we thus complete the circuit, provided the series is sufficiently extended.

MAGNETISM.

Q The loadstone, in which the magnetic property was first discovered, is an ore of iron, generally of a dull grey colour, found in several parts of Asia and Europe. The obedience of iron to an attractive influence from this mineral was observed in a very early age of the world; but the delicate tests which the present state of philosophy furnishes can detect various degrees of susceptibility of magnetic influence in many of the metals, and even in other bodies; although iron, and the minerals which contain it, are chiefly susceptible.

R But it is not until iron is converted into steel that it is capable of *retaining* those peculiarities which constitute a magnet; and the chief of these were not perceived by the first discoverers of the attractive influence of the loadstone. These peculiarities of a magnet are,

I. *Polarity—its two extremities being endued with contrary propensities; so that, whilst one of its ends attracts, and is attracted by, one end only of another magnet, its other end will have the contrary effect of repelling it.**

1. Thus, if we bring one of the little magnets used as children's toys, to the compass needle of the globe, one of its ends, when presented to the pointer marked N, will drive it away, whilst the other will attract it.

II. *The very evident attraction of iron generally.* (This probably was all that was known for several ages.)

1. Dip either of the ends of a magnet into a quantity of common iron-filings, and they will cling to it so tenaciously as to be wiped off with difficulty. The filings do not adhere to the middle of the magnet.

2. The lungs of the workmen in the large grinderies of cutlery at Sheffield, are now preserved from the very injurious influence of the invisible particles of steel which formerly impregnated the air, and which they consequently inhaled, by means of the erection of large magnets near their several grindstones.

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* The middle of a magnet is neutral, and exerts no power.

III. *The property of imparting its power to other iron by friction or other contact, or even by mere approach without actual contact.* The latter, (like the analagous effect of an electrified body, see K p. 196,) is called *Induction.*

1. Select a needle that has not too flat an eye, and rub it lengthwise with the two ends of a horse-shoe magnet: the hard steel of the needle is now, itself, permanently magnetic; and if laid right and left upon a smooth table, its polarity will be apparent when the two poles of the magnet are presented to it similarly and at once, by its rolling away before it.

2. Present a bar or straight magnet within a quarter of an inch of the end of a little bar of unmagnetised iron, (an inch in length of very thick soft iron wire, or a small key,) and it will be found that, whilst thus held, the wire or key, although not touching the magnet, possesses magnetism at its remote end, as well as that which is nearer to the magnet.

3. A large magnet presented near a watch will stop it by exerting its influence on the steel balance-wheel. The watch may go on again when the magnet is removed; but the wheel will have become permanently magnetic, and the watch must be provided with a new one.

S But what principally concerns *us*, is the *directive* property of the magnet, or that by which, when freely suspended, *one of its ends is directed towards some certain point of the horizon* of any place on our earth.

This point of its direction is different on different parts of the surface of our globe. Thus, whilst in some places it is exactly *along* the meridian, or duly north and south, (as near New York,) in other places its deviation from the meridian is considerable, as in London 24½° westward; and *in some places it actually stands at right angles to it,* thus pointing east and west!

T The intenseness also, (if we may use the expression) of this pointing of the poized magnet, varies with the station from which it points. Thus, there are some places where, if a bar or needle of steel be exactly balanced, being freely suspended by its middle, and afterwards be magnetised, it continues to be balanced as before; but such stations on the earth's surface are few, lying nearly in a line surrounding it like an equator, and indeed deviating from the real equator only about 12° on each side of it. In all other parts of the earth the balanced steel, when thus rendered magnetic, no longer hangs in equilibrio, but *dips* one of its ends. In London this dip is 69° 38′, or within 21° of rendering it perpendicular. As we approach the north polar regions this dip becomes greater; and *at a certain point of the surface there* it actually assumes the perpendicular, and becomes useless as to its directive power.

Southward of the line of stations described above, and named "the Magnetic Equator," the dipping is of the other end or that which points towards a spot within the *Ant*arctic regions.

v Now the pupil who may have noticed the peculiarities of a magnet, and will consider these positions, which, when freely suspended, all magnets will assume in those different stations of the earth, must be prepared to allow *that the earth is acting upon them* by an exclusive attraction, *as if it were itself a huge magnet* with the polarity, or power of its extremities, sufficient to be felt *in some degree all over its surface*; and yet that the intenseness of this power is so arranged as to indicate that, though not coinciding with its poles as a rotating globe, (since, if they were, every magnet would point *exactly thither*,) these two magnetic poles are each of them within a polar region or frigid zone, and that the one nearer to which we are living must lie in west longitude, and not far from the longitude of New York.

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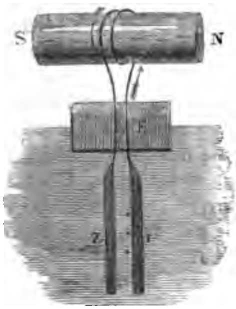
w The paragraphs on electricity given on pp. 196-9, were necessarily introduced for the purpose of furnishing a correct idea of magnetism; because the discoveries of the last few years have established the fact, that magnetism in any body, (whether temporary or permanent magnetism,) is only a result of *spiral circuits of electricity flowing around that body* in a direction at right angles to the exertion of its magnetism; the most powerful magnets being now produced by contrivances which insure such spiral electric currents, and the phenomena themselves of electricity being fully and powerfully developed, by so arranging large magnets as that the influence encircling them may be conveyed and accumulated for experiment.

X We now refer to what is stated in M and P, pp. 197-8, requesting the pupil to read those lines; and we introduce a representation of a very simple apparatus, which may fix an idea of what we have described and furnish an introduction to what follows.



The figure represents a *modification* of De la Rive's battery.

Let F be a float (as of cork).

Z a slip of Zinc.

C a slip of copper.

A copper wire passes from the copper slip through the cork, and is coiled around a very light scroll of paper; descending again through the float or cork to join the slip of zinc. The whole is then floated in acidulated water.

The fluid acts upon the zinc, which streams forth its electricity to the copper, (as shewn by the three little arrow-heads,) and the electricity is conducted up the copper wire around the scroll, and descends through the cork or float to the zinc, to complete the circuit. The effect is to magnetize the scroll; and N and S respectively display their polarities, and direct themselves into the magnetic meridian.

⁂ The pupil will please to remark, that the scroll introduced within the helix of the wire represented above is supposed to be of paper only; any substance will answer the purpose, the magnetic power resulting from the current of electricity only whilst it is proceeding, and not from the substance itself. A steel needle, however, so placed, will be found to have gained permanent magnetism.

Y The question now arises, whether the mass, or rather the surface, of our earth is thus rendered magnetic. The later discoveries of philosophy point to this fact. The huge body of our globe is magnetic constantly, only because of the various, but constantly flowing, currents of electricity which are being excited by the minerals which lie beneath its surface, and of the daily partial streams of heat which its surface receives as it rotates in the beams of the sun. If the water and land, so differently affected by heat, (W p. 174,) had been uniformly distributed, instead of being, as they are, very irregularly so; and if the various beds of metals and minerals were so lying that the united result of their electric streams were directed eastward or westward, it would appear that the magnetic poles of our earth might then coincide with the poles of its rotation; and our compass needle, in every station on its surface, point north and south. As it is, the combined result of these electric influences, from its irregular mineral strata, from its unequally heated surface, and from other causes, is such as to make it a magnet with its northern pole bearing about 24½° westward of us; (viz. as stated by Captain Ross, in lat. 70¼° and lon. about 100° W.,) (see Prob. IX. Sect. 1,) its other pole, of course, lying diametrically opposite in eastern longitude, and in the antarctic region, which has not yet been explored.

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z It will be interesting and useful to the pupil, to notice the correspondence of the following with the hypothesis of the earth's being, as just described, a great magnet, and with its poles so arranged.

1. We have learned, (2 of p. 201,) that any magnet exercises the influence of *induction* on an iron body presented in position near its poles, and that this is analogous to the inductive influence of electricity by an electrified body. It is further remarkable, that, like the electric state so induced by an electrified body, the magnetic polarity induced in that end of the neighbouring iron which is nearest to the end of an exciting magnet, is of *the opposite kind*, so that a "north" end induces a "south" one, and *vice versâ*.

2. We have seen too, that the similar ends of two magnets repel each other, and hence that end of the magnetic compass needle which points towards the north magnetic pole of the earth must itself be *dissimilar*, the *similar* end being repelled and directed away to the south.

We will bear these facts in mind whilst performing the following experiment.

Let the straight edge of a table be placed in the magnetic meridian, (that is, in the exact direction in which the compass needle points,) and let a little box-compass be set upon it, so as partly to overhang this edge: let now a bar* of soft iron, (say of 18 inches length,) having one of its ends marked, be held perpendicularly† by the side of the table and close to this compass box, and it will be found that the lower end, when presented to it, will powerfully repel the northward point of the needle, and attract its southward point, whilst the upper end of the bar will possess the reverse influence.

Now, that the bar of iron is thus magnetic only by the inductive influence of the earth, (2 of III. p. 201,) may be plainly proved by the two following circumstances:—

First, that by reversing the bar, the end before undermost and then repelling the northward pointer, will now as powerfully attract it, and *vice versâ*.

And *Secondly*, that if the bar, after all this, be held horizontally, or in the plane of the table, and especially if it be directed east and west, each end will alike influence both the pointers of the compass.

B The amount of knowledge at present attained, of terrestrial magnetism, is very limited and uncertain.‡ But it is a very interesting fact, which the ingenious pupil will compare with what has been stated, (Y pp. 203-4,) that "not only the *nature* of the metalliferous deposits must have been determined by their relative electrical condition; but that the *direction* of the metallic veins must have been influenced by the direction of the magnetic meridians; and *almost all* the metallic deposits in the world, *tend* from east to west, or from north-east to south-west.§ * * * It is probable that the secular and periodic disturbances in the magnetic force, are occasioned by a variety of combining circumstances. Among these, M. Biot mentions the vicinity of mountain chains to the place of observation; and still more, the action of extensive volcanic fires, which change the chemical state of the terrestrial surface; they themselves varying from age to age, some becoming extinct whilst others burst into activity."*

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* The kitchen poker will frequently serve the purpose; but the usage it sometimes receives, either in the kitchen or at the blacksmith's, may have hardened it.

† Rather in the direction of the *dip*, that is, with the lower end inclined about 20 degrees northward; but the perpendicular direction will serve for the illustration.

‡ Some philosophers have thought that there is a magnetic pole in Siberia also; but M. Gauss, of the German Magnetic Association, gives good reasons for denying this. The Antarctic Expedition, under Captain James Clark Ross, has its attention particularly directed to the discovery of the South Magnetic Pole.

§ That is, nearly at right angles to the direction of the magnet, (see S on p. 201).

C Thus the variation of the compass at any place has itself always been variable at different periods of time.

In 1580 the magnet, at London, varied .	11° 16′ E.	Its dip† being about	73° 30′
In 1660 it pointed	due North.		
In 1692 it was .	6° 0 W.		
In 1818 it became .	24° 30′ W.	Its dip being .	70° 34′
Its Westerly variation has been diminishing since.			
In 1831 it was .	24° 0 W.	Its dip being .	69° 38′

Besides the *greater* changes of Magnetism, such as those recorded above, and which are called *secular*, there are minute diurnal and seasonal variations, manifestly depending on *thermo-electric* influence; that is, on the electric state of a district as affected by hourly or annual changes in the *heat* of the sun. Such variations are called *periodical*, as they are compensated at a certain time of year, or near a certain hour of the day.

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[*] Mrs. Somerville's *Connexion of the Physical Sciences*, p. 368, 4th Ed.

[†] See T on p. 202.

INERTIA, FORCE, MOTION, VELOCITY, MOMENTUM.

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M

[D] Suppose that the body M, (represented by the dot made above,) were a mass of unorganized matter so situated in space as to be many thousand miles beyond the reach of the influence of any other body; then, if at rest, it must remain at rest; or if in motion, it must continue to move, and that in one direction and at one rate for, at least, those many thousand miles.

This total incapability of changing its state, is termed the *Inertia* (inertness) of matter; but the word is applied also, with less consistency, to its susceptibility of every influence that may be exerted upon it; or that entire passiveness, in consequence of which the smallest other portion, in any manner presented to M, must have altered its condition, either by putting it in motion, or by retarding, or accelerating its motion, or by perverting its course.

That which acts to produce, or destroy, or alter motion, is called *Force*. One of the earliest observations of childhood is, that force must be proportioned, unitedly, to the quantity or mass to which it is applied, and to the degree of any proposed change of its condition.

[F] *Velocity*, or the rate of motion, is measured by the space through which a body moves in a given time, as a second, a minute, &c.

[G] The *quantity of motion* communicated to any body, is estimated by the mass moved in connexion with its rate or velocity; and, since matter, in consequence of its inertia, retains, whilst unopposed, any quantity of motion impressed upon it, and is thus always ready to exhibit a resistance to any body obstructing its course, a moving body becomes itself a means of force, and the degree of this force of its motion, is called its *momentum*.

"It is, in fact, as though a transfer of the force took place from the moving body to the body moved; as though it were *poured* into it like water from one *vase* into another." —*Moseley's "Illust. of Mechanics,"* p. 243.

The momentum may consist in the little velocity of a large mass, or in the great velocity of a small one.

1. Two balls of soft clay, of which one weighs one pound, and the other nine, being suspended by separate cords from the same point; if the smaller (of one pound weight) be drawn back and driven with a velocity of *ten* feet per second against the larger one, (of nine pounds, and at rest,) their united mass of ten pounds will move forward with a velocity of *one* foot per second; the momentum thus still continuing equal, but being diffused through a ten-fold mass and therefore acting with a tenth part only of the former velocity.

H To every action, or application of force, there always results an equal and opposite re-action from the body subjected to that force.

This is often not palpable, although always true.

1. The scullerman, who pushes off his little boat with great swiftness from a ship, produces a corresponding *quantity* of motion in the ship itself; but the motion impressed upon the ship is invisible, being distributed throughout its mass.

2. The exploding gunpowder impresses as much moving force on the cannon and its carriage, as it does upon the ball that issues from its mouth; but the velocity is less in the ratio of their masses, and the friction and tackle provided for that purpose, suffice to resist the momentum.

K *Uniform Velocity* results from the application of force for one instant only.

Example: *the rotation of the earth about its axis.*

Accelerated Velocity, or the accumulation of motion or momentum, results from the continued application of force upon a freely moving body, in the direction of its course.

Retarded Velocity, or the gradual destruction of momentum, results from the continued opposition of force to a moving body in a direction the reverse of its course.

1. If a cannon be fired* perpendicularly from a precipice of sufficient height, the ball, which if fired horizontally, might travel through 1,200 feet in the first second, would in this instance, fly through 1,216 feet, or 16 feet additionally during that second, in consequence of that tendency to the earth which all unsupported bodies obey.

2. For the same reason, the ball, if fired in the exact direction of the zenith, would travel only 1,184 feet, or 16 feet *less* in the first second.

⁂ In either case the effect upon the ball would be taking place during the whole second.

3. A stone rolled off a precipice, during the first second after it has left its support falls through 16 feet. But the pupil must be guarded against the idea that it falls through one of these 16 feet in the sixteenth part of that time. During each of the many hundred wavings of a gnat's wing which can take place in that second, the falling stone is passing through a larger portion of those 16 feet than during the one which preceded it. The first portions of these 16 feet are gone through with comparatively little velocity, and the momentum so accumulates, that *near* the end of the second the rate is 30 feet, and *at* the end of the 16 feet the stone is moving at the rate of 32 feet per second.

L. In reading the following, the pupil is requested particularly to observe :—

1. Each succeeding second's operation of the force which causes an unsupported body to fall, not only propels it through an additional space of 16 feet, but produces a momentum which adds 32 feet per second to its velocity in every portion of the second which succeeds it.

2. That, in consequence of the foregoing, if we multiply 32 feet by a number of seconds, it will shew us the velocity a falling body acquires in that time.

3. That any odd number, as 1, 3, 5, 7, 9, &c., multiplied

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[*] In this and the succeeding illustrations, the resistance of the air is not considered: a cannon ball is said to lose 800 feet in the first 1,500 feet of its flight, by the resistance of the air.

by 16, will shew the space fallen through during the 1st, 2d, 3d, 4th, 5th, &c., second (that is, during the second corresponding in order, to the order of that odd number as an odd number).

4. That if the number of seconds occupied by the body's fall be squared, (P on p. 11,) it will shew how many times 16 feet the body has fallen: thus, at the end of the *third* second it will have fallen through *nine* times 16 feet; at the end of the *fifth* second through *twenty-five* times 16 feet, &c.

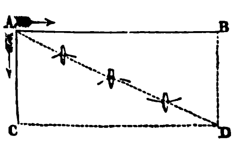
Circumstances of the descent of a body falling near the earth's surface.

In the	The space fallen through is		
1st second.	16 feet, by the accelerating influence of the earth	making 16 feet for this second.	beginning with veloc. 0 and ending with veloc. 32.
2d second.	16 feet by the earth's influence, and 32 feet independently, or by its own inertia, (such being the momentum acquired during the first second).	making 48 feet for this second.	beginning with veloc. 32 and ending with veloc. (32 and 32) or 64.
3d second.	16 feet by the earth's influence, and 64 feet by its own inertia (such being the momentum acquired during the first two seconds).	making 80 feet for this second.	beginning with veloc. 64, ending with veloc. (64 *and* 32) or 96.
4th Second.	16 feet by the earth's influence. and 96 feet by its own inertia (such being the momentum acquired during the first three seconds).	making 112 feet for this second.	beginning with veloc. 96, ending with veloc. (96 *and* 32) or 128.
	&c.	&c.	

COMPOUND MOTION, COMPOSITION AND RESOLUTION OF FORCES.

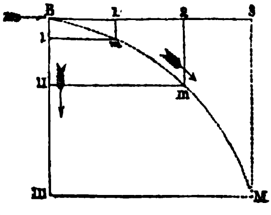
M When two or more forces, not acting in the same direction, nor in directions exactly opposite, are simultaneously urging a free body, it must hold a course between the directions of these forces. The direction of this resulting course, and the extent of it, are found by drawing two straight lines diverging from a point into the directions in which the forces act, and representing, in their relative lengths, the relative powers of the two forces; and then completing a parallelogram.

The resulting effect, both as to its direction and its quantity, is found by the relative length and *bearing* of the diagonal of this parallelogram.



Suppose a boat at A, intended to be brought to D: it will reach that point if the tide be strong enough to have conveyed it to B, whilst the rowing of its owner directed *across* the stream, is such as in still water would carry it exactly to C.

N If one of these simultaneous forces be a constant one, and therefore accelerative, (see K p. 208,) the course of the body impelled by both forces will be curved.



Thus, if the stone referred to (3 p. 209), instead of having been merely dropped from the precipice, had been flung or shot horizontally, with a force, which acting for the instant only, would have been equal, if acting alone, to the production of its uniform motion in three seconds, through the three spaces marked 1, 2, 3; then the accelerating influence of the earth would have bent its course through the points m, m, M, as described in the figure.

P The nature of this curvilinear path will manifestly depend on the relation which the projecting horizontal force bears to the degree of force which urges the body downward. The forces might be so adjusted, as to compel the body to take a circular, an elliptical, a parabolic, or a hyperbolic path. (See p. 22.)

Some Illustrations of Inertia, &c.

1. The effort necessary to keep up the motion of a carriage or wheelbarrow, is much less than that which is required to put it into motion at first.

2. In jumping, the accumulated effect of the efforts made during the *run*, is added to the force of the spring made at the leap ; and the individual is thus thrown forward to a greater distance.

3. If, whilst running or riding, a ball or orange be thrown by an effort directed perpendicularly upward, without checking speed, the ball will retain, during its ascent and descent, the forward motion which it had in common with the hand before it left it ; and, if it were not for the interference of the air, whatever the rate at which we might be moving, it would return to be caught by the hand again.

4. A steam-boat frequently travels at the rate of 15 miles per hour, or 22 feet per second. Supposing an individual, standing before the pier-glass which decorates the chimney-piece of the saloon, to jump from the floor, and to be thus one-half second in the air, it is evident that, unless whilst thus in the air he is travelling like the steam-boat, 11 feet forward, his head must be dashed with violence through this pier-glass.

5. An individual so jumping upward on deck, at 10 feet distance from the prow, would, from the same cause, if during his momentary jump, the vessel were to strike upon a rock, be precipitated 12 feet beyond her.

6. When a vessel strikes upon a rock, guns, furniture, &c., as well as men, dash forward from their places. (Dr. Arnott.)

7. If the Almighty hand were, for one instant, to arrest the rotation of our globe, every tower would be precipitated eastward ; and, together with a tremendous western hurricane, before which nothing could stand,, the vast Atlantic would overwhelm us and our neighbours of Africa, whilst the two Americas would be overwhelmed by the Pacific.

8. The rail-road train, travelling 15 yards per second, having just emerged from the arch of a tunnel, an arrow was shot from the open carriage at the key-stone of the arch, when at the exact distance of 40 yards : did the arrow reach the archway, supposing it to have been exactly one second in the air, and that the same effort would have sent it 45 yards if the individual had been standing on the ground?

PROGRESS OF PHYSICAL ASTRONOMY.

"* * * * To account for natural events—to trace their causes—to reduce them to their principles—this habit of mind * * * * seems to have been first unfolded amongst the Greeks.*" The term σοφοι ("sophists"† or "wise men,") was at first applied to those who were eminent for superior sagacity in such researches; but their sages soon preferred, and early assumed the title of φιλοσοφοι, or "lovers of wisdom," as more aptly accrediting the spirit of enquiry which actuated them. Of the Greek philosophers many of the earliest were the more patient, consistent, and successful enquirers. "The fact undoubtedly was that the physical philosophy of the Greeks soon became trifling and worthless."‡ They introduced terms vaguely expressive of certain abstract notions, and neglected experiments and facts for the logical discussion of those terms:—"as soon as they had introduced into their philosophy any abstract and general conceptions, they proceeded to scrutinize these by the internal light of the mind alone."

Pythagoras, one of the earliest of the Greek philosophers, taught the great truth that the sun is at the centre; but the study of nature "in an humble and patient enquiry after facts became despised;" and Aristotle, who lived 200 years after Pythagoras, and had been a disciple of Plato, not only obscured the science of astronomy by rejecting the Pythagorean doctrine and teaching that the heavenly bodies are carried around the fixed earth in solid orbs, but acquired an authority on subjects of physical science generally, which "commanded opinions for nearly two thousand years," and was appealed to during the inertness and blindness of the middle ages as sovereign in all matters of dispute on such subjects.

The pupil will perceive, however, in reading over the little Table of "Chronology of Ancient Observations," (see Index,) that astronomy, so much the science of observation, notwithstanding the false principles to which chiefly those observations were referred, did gain real and extended progress among the Greeks. But it is asserted that in the whole range of general physical science, there are no *doctrines* for which philosophers are indebted to the Aristotelian school. Copernicus, the Polish ecclesiastic so deservedly famous for having (A. D. 1507,) revived the just conceptions of Pythagoras, lived in times of obscurity; and the great genius of Kepler, who a century afterwards, by means of patient and laborious comparisons of his own observations and those of others, detected numerical and geometrical relations in the distances and periods of parts of the solar system, had attained no correct views of the causes of their motions, but attributed them to a force like that of the moving fluid which urges a body in a vortex.

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* Whewell's Inductive Sciences, Vol. I. page 23.

† This term was not until afterwards employed, as it is now adopted by us, to denote a *misuse* of reason.

‡ Whewell's Inductive Sciences, Vol. I. page 33.

It was to Galileo, of Florence, whose genius and labours belonged to many sciences, that the world was indebted for its first correct ideas of the compositions of motion resulting from the combination of forces. For boldly asserting the Copernican doctrine of astronomy, Galileo (A.D. 1633,) was condemned as a heretic, and imprisoned by the Inquisition; notwithstanding his invention of the telescope furnished a direct appeal to facts in the rotation of the sun about its axis, the phases of Venus, and, above all, the beautiful epitome of the Copernican system displayed by Jupiter and his satellites.

About the same time, in England, the illustrious Bacon, whose mind "surveyed the whole region of science," powerfully contributed to extricate philosophy from "the labyrinth of definitions and disputations," and to establish the true method of searching after truth.

The followers of Bacon and Galileo, especially in Italy, Holland, and England, "ransacked all nature for new and surprising facts;"* and many additions were made to the imperfect physical views of those great men with regard to the heavenly bodies, by advances towards the true theory of their motions. About the period of the civil wars, the Royal Society was formed. In 1666, Borelli, at Florence, from a consideration especially of Jupiter's system, and Dr. Hooke, in England, from more general astronomical considerations, asserted the action of the central solar force in union with the centrifugal tendency of the planetary bodies, to be the cause of their orbitual motion.

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* Sir John Herschel's "Discourse," p. 115.

But it was Newton, contemporary with Borelli and Hooke, whose transcendent genius identified the nature of this central solar force, not only with that which retains the moon about the earth, but with that also which curves, and ultimately destroys, the forward tendency of a projected stone or cannon ball; and which existing, inseparable and unalterable by any change of the state of matter as fluid, solid, &c., causes every particle in the universe to *tend* to an approach towards every other particle, in proportion to the square of its distance from it.

The wondrous generalizations and demonstrations of Newton formed "not a leap, but a flight—not an improvement merely, but a metamorphosis—not an epoch, but a termination. Astronomy passed at once from its boyhood to mature manhood."*

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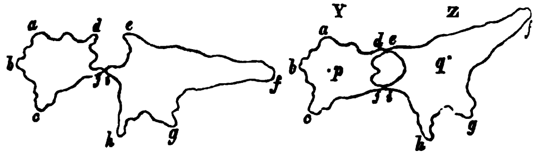
* Whewell's History of the Inductive Sciences, Vol. II. p. 180.

GRAVITY.

We will suppose* that whilst we had the needle-hole under the deep power of the microscope, (see p. 7,) after the perturbation caused by the whirling of the machinery in the head of the Vorticella had subsided, and our revolving globule has deserted the scene, there remained two still more minute specks near the centre of the field of view, which, from the irregularity of their forms, and the absence of any token of volition, we had discovered to be mere dead matter floating in the water. Our globule† diameter, found by a micrometer, scarcely exceeds the fifteen-hundredth part of an inch, and these particles were each of them little larger than the globule. They, however, approached each other, and, with an acceleration quite perceptible as they *neared*, came into apparent contact. Why was this?

To avoid complexity, let us consider these microscopic particles as existing by themselves, and magnified as they might be by the oxy-hydrogen microscope.



They were extremely irregular in surface and thickness. Their first apparent contact took place at *i* and *j*; but after

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[*] The Teacher can appreciate the difficulty of fixing attention to such a subject. The author does not pretend to have had such a microscopic view as that referred to on this page; and he is aware that even supposing them to be under no other interfering influence, *capillary* attraction may be claimed as a cause of the coming together of such floating particles. Dr. Arnott however, instances the grouping of the parts of wrecks after a storm as resulting from their gravitation towards each other; and the famous experiments of Cavendish are considered to have fully shewn the truth of the great doctrine, that every different particle exerts a force.

[†] The *grain monad*, diameter about 1-1440th of an inch.

a moment, they assumed the position given on the right; and not only *i* and *j*, but *e* and *d*, also, were in contact.

The fact is, *every* part of each of these bodies attracted *all* other parts of its own and of the other body, and all other parts attracted each part; *a*, *b*, and *c*, (of fig. Y,) were respectively attracting the whole, but least attracting *f*, (of fig. Z,) and were least attracted by it, only because *a*, *b*, and *c* were farthest from *f*—and so in considering any other portions, internal or external, of both these tiny masses.

Q The *law* (see Illust. p. 14,) under which these particles were thus influencing each other, is to be particularly remarked by the learner, for instance:—*a*, (fig. Y,) was *half* as far from *i*, as it was from *h*:—*a*, therefore, was attracting *i*, and was being attracted by it, *four* times as much as it was attracting *h*, or being attracted by it:—*b* was removed from *i* about *one-third* of its distance from *f*; *b*, therefore, was attracting *i*, and was being attracted by it *nine* times as powerfully as *b* was attracting *f*, &c., &c.

If we could specify a million of parts in each of these microscopic masses, they might each of them be described as thus acted upon by every other part, and each as acting on every other.

R How complicated is the system of means, by which two such invisible portions of matter are tending towards each other! If it were possible that lines should be drawn from each attracting and attracted part to every other part, our view of them would be overwhelmed. Yet it is the province of science to shew that there is, in each of any two masses, a point at which all the several tendencies of the several parts of the one mass towards those of the other mass *may be considered as originating*. That is, if all the attracting particles in masses Y and Z respectively, were instantaneously to shrink (retaining their real substances and attracting energy) into the points *p* and *q*; the *amount* of the attracting force of the masses on each other, and its *direction* or *tendency*, would just equal that force and direction which the particles exert from their several present situations in Y and Z; and thus if the distance of *p* and *q* could be ascertained, as well as the quantity of matter in Y and Z respectively, the force which thus holds them together might be known.

[S] We see that if the shape of either of these little masses were changed, the point where the attractive influence of its parts may be considered as centering would necessarily be changed also; since its position depends entirely on the distribution of those parts. If the several portions were to become, suddenly, free to move amongst themselves, and were to be uninterrupted in their action on each other by the water which suspends them, we know, by experience, that they would take the globular form, like the water-drop upon the duck's wing, or the dew upon the blade of grass, or quicksilver, in minute quantities, upon many things.

[T] The problem "what will be the *force* with which a congeries of particles, constituting a solid mass of any assigned figure, will attract another such collection of material atoms," * * * is, in its general form, of extreme difficulty. Fortunately, however, for human knowledge, when the attracting and attracted bodies are *spheres*, it admits of an easy and direct solution. Newton himself has shewn that, *in that case the attraction is precisely the same as if the whole matter of each sphere were collected into its centre, and the spheres were single particles there placed*. So that, in that case, the general law applies in its strict wording."—*Sir John Herschel's Astronomy*, p. 237.

"Every particle of matter in the universe attracts every other particle with a force *directly* proportioned to the mass of the attracting particle, and *inversely* to the square of the distance between them."—*Ibid*, p. 236.

[V] It was one of the errors of Aristotle, to maintain that there was an absolute or intrinsic *lightness* in certain matter which occasioned it to float. We now learn that *all* matter has gravity or weight; and that a floating body, as a balloon or a ship, maintains its place on the surface of the water or in the atmosphere, only *because it is pressed upward by the heavier surrounding body*; that is, by the greater gravitating force of a portion of the fluid equal to it in bulk. It was in the mind of Archimedes, who lived on the eve of the dark period, and who "terminated the steps of progress in physical science made by the Greeks, in a single stride," that these just ideas arose; but they were lost, and were not recovered until the time of Galileo.

W Another erroneous doctrine was, that bodies fall faster in proportion as they are heavier or require support. We must remember, that as one brick cannot fall faster for being *near* another falling brick, so it will not fall faster for being *one* of a falling mass of fifty bricks, however closely cemented to it; for the whole mass falls only in consequence of the force which is acting separately upon every part of every individual brick which helps to compose it.

EXTRACT FROM "GRAVITATION," AN ELEGANT AND DELIGHTFULLY SIMPLE LITTLE TREATISE, BY PROFESSOR AIRY, THE PRESENT ASTRONOMER ROYAL.

"Attraction is measured by the space through which it draws a body in one second of time, after the body is set at liberty."

* * * * * * * *

X The first rule is this: "The attraction of one body upon another body, does not depend on the mass of the body which is attracted, but is the same whatever be the mass of the body so attracted, if the distances are the same."

"Thus Jupiter attracts the sun, and Jupiter attracts the earth also; but though the sun's mass is three hundred thousand times as great as the earth's, yet * * * (the attraction being measured in conformity with the definition above) when the sun and the earth are at equal distances from Jupiter, the attraction of Jupiter draws the sun through as many inches, or parts of an inch, in one second of time, as it draws the earth in the same time."

Y The second rule is this: "Attraction is proportional to the mass of the body which attracts, if the distance of different attracted bodies be the same."

"Thus: suppose that the sun and Jupiter are at equal distances from Saturn; the sun is about a thousand times as big as Jupiter; then whatever be the number of inches through which Jupiter draws Saturn in one second of time, the sun draws Saturn in the same time through a thousand times that number of inches."

z The third rule is this: "If the same attracting body act upon several bodies at different distances, the attractions are inversely proportional to the squares of the distances from the attracting body." (See Illustration on p. 14).

"Thus the earth attracts the sun, and the earth also attracts the moon; but the sun is *four hundred times* as far off as the moon, and therefore, the earth's attraction on the sun is only a *one hundred and sixty thousandth part* of its attraction on the moon; or, as the earth's attraction draws the moon through about one *twentieth* of an inch in one second of time, the earth's attraction draws the sun through a little less than *one three* millionth part* of an inch in one second of time. In like manner, supposing Saturn *ten* times as far from the sun as the earth is, the sun's attraction upon Saturn is only a *one hundredth* part of his attraction upon the earth."

* * * * * * * *

"The reader may ask, how is all this known to be true? * * For the motions of the planets, calculations are made, which are founded upon these laws, and which will enable us to predict their places with considerable accuracy, if the laws are true, but which would be much in error if the laws were false. * * * It is found that they agree so nearly, as to leave no doubt of the truth of the law. The motion of Jupiter, for instance, is so perfectly calculated, that astronomers have computed ten years beforehand, the time at which it will pass the meridian of different places, and we find the predicted time correct within half a second of time."

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* The exact fractional expression $\frac{1}{3200000}$, is given in the work: this is the *one hundred and sixty thousandth part* of the twentieth of an inch, or the space through which the moon is drawn; and exactly accords with the *square* of the greater distance of the sun.

CENTRE OF GRAVITY.

[B] We have just seen (R p. 217) that there is a certain point in each of two little masses, *where* the whole force with which it attracts the other, may be represented in average distance and direction. It will readily be allowed, that since the whole attraction of either of them is the sum of the attractions of its parts, the larger of the two must be the more powerfully attractive, in the ratio of its quantity of matter. Now the earth is incomparably greater than any body on its surface; the greatest mountain being less than its fifty-nine millionth part. All bodies, therefore, on the surface of the earth, have an amount of attracting force exerted upon them, from the whole body of the earth, so great as to render their attractive influence on each other altogether imperceptible,* except under very peculiar circumstances; and, since the earth is globular, and the amount and tendency of the attractions of all its parts (as shewn by Sir Isaac Newton) the same, on this account, as if these attractions were all condensed at its centre, (T p. 218,) we speak of this, the gravity or weight of a body, as *centripetal* (or centre-seeking) *force*.

[C] Common experience shews us that the earth's attraction may be counteracted, not only by applying underneath the whole side of a body a substance on which it may rest; but that one certain point may easily be found, *at* which, or *underneath*, or *above* which, it may be balanced or sustained by suspension or propping. This point, in any given mass, is always the same provided we do not alter its form, however irregular that form may be, or however we may turn the body about; although it is evident that in each different position of the body, the dragging force of the earth upon each particle lies in a new direction through the mass. The point is called the *centre of gravity*; it is *where*, if all the weight of all the molecules of the body thus balanced could be taken from each of them and collected, that weight might be condensed without disturbing the body.

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* The experiments of Cavendish, made at the end of the last century, were most delicately conducted on several masses of lead, two of the largest of which weighed 3 cwt.; and his whole apparatus was inclosed in a room, without door or window, light being reflected upon it from a small lamp, and his view being taken by a small telescope fitted into an aperture.

Observations made on plumb-lines, hung from the brows of mountains, have also detected very small deviations from perpendicularity in the suspending cord, owing to the local attraction of the mountain-masses on the plummets.

D The situation of this point within a body perfectly symmetrical, and having its atoms or particles equally distributed, as within a globe or cylinder or ring of uniform density, is plainly at the centre of its magnitude. But the centre of gravity in numerous instances, is not at the centre of the mass. Thus, a long stick having a *ten* pounds' weight attached to one end of it, may be kept in a horizontal or balanced position by a weight of *one* pound, if supported at a point distant from the latter in proportion to its lightness; that is, ten times nearer to the end which has the greater weight.

Two bodies so united, may properly be called a system (a putting together). If the stick be of uniform substance, it may evidently be left out of the question, its use being regarded only as that of a connector of the weights.

Now the stick itself exists as this connector, only because of the attraction of the particles throughout its length (see D p. 167). Let us then imagine the stick removed, and an *invisible* agency, such as that which is really at work in keeping the particles of the stick together and therefore sufficiently powerful to supply the place of the stick, and we have still *a system* the centre of gravity of which is *at* the same point as before.

If we now conceive the equilibrium of the two bodies thus invisibly connected and balanced, to be disturbed, so that beginning to fall the one is in advance of the other; and at the same instant, the earth to drop away from them whilst they follow it at a considerable distance, we shall have an idea of the way in which a planet and its satellite revolve about their common centre of gravity, whilst pursuing their course around the sun.

F We have learned (G p. 207) that the *quantity of motion* is measured by the mass considered with its velocity. In the case just imagined, the mass of the ten-fold weight, being distant from the centre of gravity only one tenth of the remove of the balancing one pound weight, is carried around that centre of gravity with but one tenth of its velocity; and thus the quantity of motion is just equal to that of the smaller and swifter body. If the larger of these two bodies had been much more ponderous, the centre of gravity would have been proportionably nearer to it, and might have been within its surface. The magnitude of the earth is at least 40 times that of the moon, and their distance from each other being 240,000 miles, their common centre of gravity is thus 6,000 miles from the earth's centre, or at a point only 2,000 miles on the outside of its surface. The centre of gravity of the earth and the sun, is not quite 300 miles from his centre; such indeed is his magnitude, that the common centre of gravity of the whole system lies considerably within his mass. In consequence of the combined attractions of the planets, his body is in motion around this point; and referring to the definition of *quantity of motion* (G p. 208, Note), we may say that there is as much motion in the sun as in all the planets together!

CENTRIFUGAL FORCE.

G Motion occasioned by a single force, must be in a straight line:—When matter is moved about a centre, there is necessarily a composition of at least two forces:* If, at any instant, the effect of one of these two forces cease, or be overmatched, obedience to the other force will carry the body in a straightforward direction.

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* Whether the force exerted from the centre be such as we have to consider elsewhere, discernible only by its effect on the circling body, or whether it consists in the attraction of cohesion, (p. 167,) or holding together of the particles of a string, &c.

The readiness displayed, in consequence of its inertia, by any circling body, to run away in a direction which is *tangent* (page 17) to the point *where* it is at any instant, is called its *centrifugal,* (or centre-fleeing) *force.* This is illustrated in the common sling—the ignited particles of a "Catherine-wheel" fire-work—the trundling of a mop—the "Governor" of a steam-engine.—A grindstone may be turned at a rate which will cause its compact rim to fly off into splinters.

WHIRLING TABLE.—There is a philosophical machine called a *Whirling Table,* by means of which a weight may be made to revolve with any proposed velocity, at a proposed distance from the centre; and thus to exhibit the amount of the centrifugal tendency produced on it by that movement, as it draws up weights suspended from the centre.

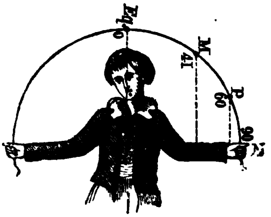
From this machine, amongst other results, the following are obtained, viz.:—

H A weight whirled with the *same* angular velocity (p. 100) as another equal weight, but at a *double distance* from the centre, exhibits a *double* centrifugal tendency, and so on in proportion for any increased distance.

Because, at double the distance from the centre, the circumference through which the weight travels, is double (P page 2): and thus the velocity being double, the quantity of motion to be controlled into the curved path is double also.

K A weight whirled at the *same distance* from the centre as another equal weight, but with *double revolution in the same time,* exhibits a *fourfold* centrifugal tendency:—if whirled with a *threefold* velocity, a *ninefold* tendency, &c. A double or treble weight, under these circumstances, exhibiting a double or treble result.— See Cab. Cyclop. "*Mechanics.*"

Double revolution in the same time, *i. e.*, double the number of bendings into a circular path, (even if no additional momentum were generated by it), would evidently require a double energy to control it; but by double velocity the momentum also is doubled, and this alone requires double control: thus the counteracting weight at the centre must be as the square, or *fourfold*.



The use of the skipping-rope, if we accommodate ourselves (as on p. 100,) by supposing that it *can* take the semi-circular form, and that our young friend (exhibiting above, who holds his hands apart to about two-thirds of the length of his rope,) is sufficiently skilful to lift his feet at the jump without disturbing the position of his hands, will afford us an illustration of the centrifugal force, as it affects the inhabitants of our rotating earth in their several latitudes. (See also Prob. XVIII., Sect. 1.)

A globe or sphere is defined to be "the solid generated by the revolution of a semicircle about its diameter, which remains fixed:"—Thus our skilful skipping friend, under such circumstances, may be said to cut out the surface of a globe of air.

The imaginary line joining the handles will, then, be the *axis*, and the extremities of the handles *the poles*.

If we take the liberty of tying two or three knots in the rope, it is obvious that the knot which passes directly over his head, and which may be considered as on the equator, has the greatest velocity; and of the others in the right-hand quadrant Eq N, that nearer to Eq has greater velocity than that nearer to N; and this *in direct proportion to their distances from their centres of motion*; that is, from the points in the arm and wrist, or the imaginary axis around which they are revolving.

For instance, that marked M 41, is moving in a circumference, of which the radius (from M to the arm) is three quarters of the line joining Eq and the chest; whilst that marked P 60, is moving in a circumference of which the radius (from P to the wrist) is only one half of it.

Hence the different *rates* at which they are moving have this proportion, and consequently, their centrifugal tendencies have it also (H p. 224).

Hence arises the *pull* which our friend finds, *tending to bring his hands nearer to each other*, and to render this globe of air an oblate or flattened one: a pull increased, if the energy of the skipper be increased, in the ratio of the *square* of the increased angular velocity (see K p. 224).

M By referring to this figure, (and to that on page 16,) it will be seen that M 41 and P 60, are the *cosines* of the arcs Eq M and Eq P. Hence *the rate of diurnal motion* of any inhabitants of the globe, corresponds with the *cosine of their latitude*; and since the circles in which they move have each of them their 360°, *the length of a degree of longitude* in any given latitude must also be in that proportion.

N In consequence of its inertia, (see illustration on p. 212,) a stone, whilst dropping from the hand to the ground, retains that influence of the centrifugal force which it had in common with the hand, and with every thing around, before it left it, and really falls the slower for it; the centrifugal force being the antagonist of the centripetal force or gravity, which it obeys in descending.

Thus terrestrial *Gravity* (strictly speaking) is the whole attracting force of the earth considered as at rest: *Gravitation*, that which remains after the centrifugal counteraction arising from the earth's rotation is deducted.

Referring to K p. 224, if our globe were to revolve in 12 hours, *i. e.*, in *half* the time occupied in its present daily rotation, the centrifugal force in any given latitude would be *four-fold* of what it is: if it rotated in eight hours, or in one third of the time, the centrifugal force would be *nine-fold*: if in six hours, or one *quarter* of the time, *sixteen-fold*, &c.

P In consequence of the great bulk of Jupiter, and the energy of his daily rotation, the centrifugal force in any latitude on his surface is 66 times that of a corresponding latitude on our earth; nearly one-eighth of the gravity of his huge attracting mass being thus counteracted at his equator.

THE PENDULUM.

The pendulum of the common clock is a body obeying the attracting force of the earth, which, during the half-second of its falling, is acting on its inertia to accelerate its motion, and during the half-second of its rise, to retard it in like manner, until this force again overcomes the inertia of the pendulum, and effects its descent.

Q Now it is obvious, that if the whole of the matter in our earth so attracting the ball of the pendulum, were acting as if *all* that matter were stationed, strictly speaking, at the *centre*, (page 218,) that is, if the earth were a perfect sphere, and at rest, the pendulum would be equally affected by it on every part of its surface. But two things affect the vibration of the pendulum, and in consequence, the going of our clocks when carried into different latitudes. 1st. The centrifugal force, which, as we have seen, is in its measure counteracting the attracting force unequally in different latitudes. And 2nd. The unequal distance of the centre of gravity from the different parts of the surface, arising from the change of form impressed upon the earth itself by this centrifugal force.

Both of these have been recognised, and both rendered available as means of determining the figure of the earth.

"The *ellipticity* of the earth's figure was discovered and demonstrated by Newton,* to be a consequence of its rotation, and its amount actually calculated by him, long before any measurements had suggested such a conclusion."

R "Experiments made with the greatest care, and in every accessible part of the globe, have fully demonstrated the fact of a regular and progressive increase in the weights of bodies, corresponding to the increase of latitude."—*Sir John Herschel's Astronomy*, p. 126.

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* The circumstance which led, in the first instance, to this enquiry, was the observation made by Monsieur Richer at Cayenne (about 4° from the equator). He found that his clock pendulum, which had vibrated an exact second at Paris, needed shortening to make his clock agree, at Cayenne, with the time correctly shewn by the passage of a star across the meridian (see definition 83, *note*).

Because, as the earth is ***flattened*** at the poles and ***bulges*** at the equator, its centre of gravity is nearer to the inhabitants of the polar, than to those of the equatorial regions; and because, in addition to this, the parts more distant from its axis have the greater centrifugal force.

S "From these experiments it appears that the extreme amount of this variation of gravity, or the difference between the *equatorial and polar weights of one and the same mass* of matter, is one part in 194 of its whole weight."—*Ibid.*

That is to say, a body weighing 194 lb. at the equator, would weigh 195 lb. at the poles; or the intensity of the attractive force on a pendulum at the equator is 194th part less than at the poles. Hence, the pendulum which vibrates in a second in any given latitude, will vibrate more slowly in a lower latitude and faster in a higher latitude; and to make its 60 vibrations in an exact hour it must be lengthened or shortened accordingly.

T Newton and eminent mathematicians of the Continent, have shewn by "purely mathematical investigation," that the degree of oblateness of figure impressed on the earth by its rotation, ought to affect weights, not as above by $\frac{1}{194}$ but by $\frac{1}{230}$. The difference between these two quantities, may easily be found by any one acquainted with vulgar fractions, to be about $\frac{1}{289}$. And it is worthy of most attentive remark, that the last fraction is that which *the mathematician gives* as the amount of the centrifugal force at the equator, if we give him the dimensions of our earth, and the rate of its diurnal rotation.—See *Sir J. Herschel's Astronomy*, p. 128.

MEASUREMENT OF A DEGREE OF THE MERIDIAN.

V The "Ellipticity" or oblateness of our earth, has likewise been ascertained from actual measurements of several portions of that outline of it which passes through its poles, that is, of a "Meridian."* Measurements of this kind, to ensure greater exactness, are still proceeding in different latitudes.

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* Its polar diameter is less than its equatorial diameter by 26½ miles.

The first expedition for this purpose took place under the auspices of the French Academy of Sciences, in 1735, when some of the continental astronomers, differing from the opinion held many years before by our own great Newton and the celebrated Dutch mathematician Huygens, and contending that the earth was a *prolate* or lengthened body and not an *oblate* or flattened one, discovered, to their surprise, that a degree of the meridian near the pole was *longer* than a degree of the meridian near the equator; that is, that the earth curves more in a short space, or makes up its degrees of curvature northward or southward, somewhat quicker near the equator than in higher latitudes; and hence, that the Polar regions have a comparatively flattened curvature, like that of a larger circle.

Suppose an individual in lat. 80, to have his head directed to a certain star: if he travel northward until his head is directed to a star *one degree* nearer to the Polar point, and use the means of correctly measuring the line of his road, he will ascertain *the length of a degree of the meridian.* Now it is found that an inhabitant of the equatorial regions so travelling to point his head to a star one degree northward of the equinoctial, need not proceed quite so far as one of high latitude. Hence the difference of his direction from the centre (see L on p. 2) is made in shorter space by him than by one who lives nearer to the Pole; that is, the meridional outline of the earth is *flatter* near the pole, or less curved in the same distance.

W "The ocean occupies indifferently, all latitudes, with no more partiality to the polar than to the equatorial. Since then, as we see, the water occupies an elevation above the centre no less than thirteen miles greater at the equator than at the poles, and yet manifests no tendency to leave the former and run towards the latter, it is evident that it must be retained in that situation by some adequate power, * * * * therefore, either the earth is not at rest, or is so internally constituted as to attract the water to its equatorial regions and retain it there. * * * * * The former is in accordance with all the phenomena of the apparent diurnal motion of the heavens; and therefore, if it will furnish us with the power in question, we can have no hesitation in adopting it as the true one."—*Sir John Herschel's Astronomy*, p. 119.

ORBITUAL MOTION.

X We have seen (G on p. 224) that the velocity of a revolving body may become so great as to generate a centrifugal force too powerful for the centripetal force; that is, too powerful for its connexion with the centre of its motion, whether that connexion be the adhesion of the parts of a grindstone, or of the parts in the length of a string. There is therefore a *limiting* velocity, or one which answers exactly to the *utmost possible* stretch of the string, &c., *i. e.*, to the *exact* adhesive force of its parts, or of those of the grindstone; and this exact velocity can be calculated easily if mathematicians know the *strength* of the string, the *firmness* of the grindstone, &c. The circumstances will evidently be the same, if the connexion with the centre be not operating, so to speak, step by step, from particle to particle, as in the length of a string, but be only a line of attractive influence imperceptible except in its action on the revolving body. It is calculated* that, exactly affected with "weight" (centripetal force) as matter is on the earth's surface, a stone, or any other mass, must have a velocity which would carry it around the earth in 1h. 23m. 22s., in order that its centrifugal force might exactly balance that attraction or weight; *i. e.*, that the stone, &c., might not need *to rest upon* the surface.

If, therefore, our earth's rotation were performed in this time, matter *on* its surface would have its weight exactly counteracted; the pendulum would altogether cease to vibrate,—muscular power would have nothing to do,—the tops of our mountains, or even of our buildings, no longer dependent on their foundations, would move eastward as satellites—the air and the ocean lose all their properties of pressure, and a total subversion of terrestrial existence take place.

Y The moon is performing her orbit about the earth in 27d. 7h. 43m., at a distance, as ascertained by her parallax, (P on p. 19,) equal to about 60 times our own from the earth's centre. It is calculated† that if, *whilst still affected*

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* See Sir J. Herschel's *Astronomy*, pp. 234—236.
† Ibidem.

with its earth's surface weight, a stone could be whirled by a cord at such a distance from the earth's centre as the moon is, it must circle with a velocity 60 times the moon's, or in 10h. 45m. 30s., in order to have that weight exactly counteracted by its inertia, and revolve as she does. Experiment by the whirling-table, (K. p. 224,) as well as calculation, shews that this *sixty-fold* energy of the revolution of the stone generates a centrifugal force requiring a centripetal counteraction equal to the *square of sixty*, or 3,600. The moon, therefore, if retained in her orbit by the earth's attraction, must be *weighed down towards it* with a force 3,600 times less than this supposed revolving stone; that is to say, the course of her orbit is such as is produced, unitedly, by her straightforward motion, arising from her inertia, and by her *falling* through (not 16$\frac{1}{12}$ feet, as bodies fall at the surface of our earth,) but through the 1-3600th part of this space in one second of time :—a quantity just according with what is due to our earth's attraction on her at her sixty-fold distance!

Newton had retired from Cambridge in 1666, on account of the plague. (He was then 24 years of age.) As he sat alone in a garden, he fell into a speculation on the power of gravity; that, as this power is not found sensibly diminished at the remotest distance from the centre of the earth to which we can rise, neither at the tops of the loftiest buildings nor even on the summits of the highest mountains, it appeared to him reasonable to conclude, that this power must extend much further than was usually thought: why not as high as the moon? said he to himself; and if so, her motion must be influenced by it; perhaps she is retained in her orbit thereby. * * * Newton's superiority here was, that he conceived the celestial motions as distinctly as the motions which took place around him; considered them as of the same kind, and applied the same rules to each without hesitation or obscurity.*

"The planets *are in motion*, and it is of no consequence to our enquiry how they received this motion; but it is convenient, for the purposes of calculation, to suppose that, at some time, they received an impulse of the same kind as that which a stone receives when thrown by the hand; and this is the whole meaning of the term "projectile force."—*Airy on Gravitation*, p. 16.

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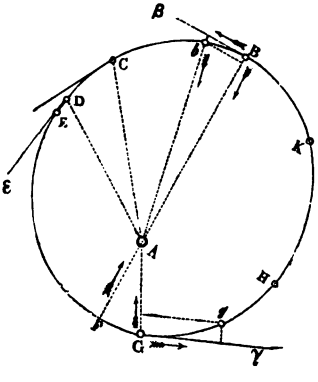
* Whewell's *History of the Inductive Sciences* (quoted there).

[Z] But the curvature of the path of the stone is caused by an attraction which, although constant and therefore accelerating, is acting *equably* during every instant of its descent, however high the precipice from which it is projected; since the summit of the loftiest mountain is not significantly removed from the earth's centre, and attraction is equally powerful *there* as in the lowest valley into which the stone might fall.

The circumstances of the orbitual motion of any heavenly body, are circumstances on so grand a scale, that, when we consider an approach of one of these toward another, or its recess from it, we must bear in mind that its inertia is being acted upon by a force continually increasing or decreasing in the ratio of the squares of the distances of the centre of the one from the centre of the other.



[B] In order that the curve of its path may be *circular*, the projectile force of a planetary body must be so adjusted, that the tangent B β (in which its inertia at a certain instant tends to carry it) may be at right angles to A B, (the line in which the attractive force, of that instant, is acting,) and that too at the same instant that the momentum of the body is exactly such as would be acquired by a mass falling half-way from B to A. This condition is fulfilled in none of the bodies of the solar system; and hence their orbits are ellipses or ovals, each of them in some degree alternately approaching and receding from its primary, which is situated in a focus of its elliptical path.

[C] A planetary body at B, is endowed, at a certain instant, with a projectile force sufficiently feeble to allow that the power which A exercises, even at its greatest distance A B, should render its curve less "flattened" than that of a circle; that is, the *centripetal* force having then relatively, greater power, gains upon the centrifugal force, and, in a certain time, draws the body nearer to A (its source) by a space equal to the difference between A B and A *b*.

D In doing this, however, the centripetal force is (if the expression may be allowed) fostering an antagonist; for all additional momentum gained by the body in thus falling towards A, is retained by it in consequence of its inertia (4 p. 212); and, provided with this and the momentum still additionally supplied in passing towards C, it gets *there* into circumstances in which attraction towards A additionally favours its progress; for *there* (at C and D) the influence exerted from A "helps it along its path, just as when a ball rolls down a sloping bank the force of gravity (whose direction is not much inclined to the bank) helps the ball down the bank, and thereby increases its velocity."

Let E be the point to which it thus arrives in a quarter of the time of its orbitual revolution. During this time the body has been falling towards A, inasmuch as A E is shorter than A B; and this approach has been made with a velocity constantly augmenting,—not only (as the stone's velocity) in consequence of the continuance of the force of attraction; but, as well, from its "nearing" A, the source of it.

F But velocity so furnishes centrifugal force, that when the body has arrived at E, its tendency to depart in a tangent (as E ϵ) is sufficiently strong to be a match for that part of the augmentation of its velocity* of approach to A which would result from its lessening distance; and thus, although continuing to approach until it arrives at F, its acceleration along the arc D F is no longer chiefly due to the *direct* centripetal force existing at A; but only to it indirectly, *i. e.* as a cause of the accumulation of centrifugal force. The planet arrived at F, is possessed of momentum which overmatches the attractive force of A; and it begins at that point to recede from it.

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* "Upon making the calculation more accurately, it is found that the planet, after leaving B, approaches to the sun more and more rapidly for about a quarter of its time of revolution; then for about a quarter of its time of revolution the velocity of its approach is constantly diminishing."—*Airy on Gravitation*, p. 19.

But it now becomes retarded:—for the direction of A's attraction upon it after it has passed E becomes more and more opposed to its centrifugal tendency; and it gradually[*] yields to it as it passes on, through H and K, to complete its course at B with a velocity exactly such as it had before it left it.

G We may regard the above either as the description of the moon's orbitual revolution around the earth of 27d. 7h. 43m., or as that of the earth's around the sun of 365d. 6h. 9m. 9s.; or as that of any other planet, primary or secondary.

We have seen (Y, p. 231) that the moon's *period* of revolution, considered with her distance as discovered by parallax, is such as is just necessary to produce that centrifugal force which is a counterbalance to the force of attraction exercised on her by the earth at *such* a distance.

From the known distance of the sun (similarly found by parallax (H, p. 19) the velocity of the earth's motion around him is likewise known; and from a consideration of the earth's mass and its velocity, its momentum or centrifugal force is known.

H Now like the stone's or the moon's (see p. 231) this centrifugal force of the earth must be the exact counterbalance of the sun's attraction:—What then is the sun's attraction, which, although exerted at a distance equal to 400 times that of the moon, thus equals such centrifugal force of the earth?

Sir John Herschel informs us that it equals that which would be exerted by a collection of 354,936 earths occupying its place. This then is the quantity of matter existing in the sun:—" a ponderous mass, calculated to exhaust the feeble attractions of such comparative atoms as the earth and moon, without being dragged from its place. Their centre of gravity (F, p. 223) lies almost close to the centre of the solar globe, at an interval quite imperceptible from our distance; and whether we regard the earth's orbit as being performed about the one or the other centre* makes no appreciable difference in any one phenomenon of astronomy."

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[*] "Just as the force of gravity retards a ball which is bowled up a hill."—*Airy on Gravitation*, p. 20.

K The pupil must be guarded against inferring that the orbits of the planets are as excentric as the diagram on which the character of their motions has just been described. The earth's orbit is so nearly circular, (its excentricity being only 1-60th,) that if correctly drawn upon a table, (as we have supposed on pages 106-8 &c.,) it will require a nice eye to detect its ellipticity; yet this 1-60th of excentricity producing a deviation in distance from the sun of its double or 1-30th of our average distance of 95 millions of miles, he is perceptibly larger to astronomical measurement in December than in June. Venus's orbit " is still more nearly circular than the earth's: Jupiter, Saturn, and Uranus, have a difference of about one-tenth between their greatest and least distances from the sun. Mars has his extreme distances in the proportion of five to six nearly; and Mercury in the proportion of two to three: * * The orbits of the satellites of the Earth, of Jupiter, and of Saturn, are also nearly circular."†

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* That is, about the centre of gravity, or the centre of the sun's magnitude,—*Astronomy*, p. 239.

† *Whewell's Bridgewater Treatise*, p. 156.

KEPLER'S LAWS.

L Even those of ancient astronomers who held the true Pythagorean doctrine that the planets compose a *Solar* system, or have the sun as their centre of motion, supposed that their orbits were *exactly* circular, and their velocities uniform. From observations on the planet Mars, partly his own, but chiefly those furnished to him by the labours of Tycho Brahe, Kepler discovered that motion in an elliptic path alone (with its consequent accelerations and retardations) could reconcile the places and appearances of that planet with each other. His later observations on the other planets tested the law of elliptic motion as belonging to them all.

M Kepler's *second* discovery was the very remarkable one that *the Radius Vector of a planet's orbit sweeps over equal spaces in equal times.* Thus suppose the earth to proceed from B to *b*, (see p. 232,) in the *three* weeks which succeed the 1st of July, and after *six* weeks more to be at C; then after the next three weeks it will arrive at D; but the six weeks' space contained between C A and *b* A, (and throughout which we may suppose the rays falling from A upon the planet to have passed during those six weeks) will be alike double of the *longer* three weeks' space *b* A B, which preceded it, and of the *shorter* three weeks' space C A D, which succeeded it.

N Kepler's *third* discovery proved that "a fine bond of relation involves the whole system, and gives to it a distinct and definite *oneness: exhibiting it, as it were, as an individual.*"* *The squares of the two numbers of days (or hours, or minutes,) during which any two planets respectively perform their orbits; have the same ratio that the cubes of the two numbers of miles, &c., of their respective average distances from the sun have.*

Thus, if we square the number 1, as representing one year of our earth, and likewise square $11\frac{8}{10}$ years, the time fulfilled during Jupiter's year or orbitual revolution, we obtain the numbers 1 and $141\frac{41}{100}$. Then 1 divided (R, p. 11) into 141, gives almost exactly the ratio between 1, the cube of *one*, (or our earth's distance from the sun) and the cube of $5\frac{2}{10}$ of her distances, or the distance of Jupiter from the sun.

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* Nichol's *Phenomena and Order of the Solar System,* p. 116.

So, if we divide the *square* of the $10{,}759\frac{2}{10}$ days of Saturn's year or periodic revolution, by the *square* of the $4332\frac{1}{10}$ days of Jupiter's year, we obtain a number which is almost exactly the quotient (or number expressing the ratio) which is found by dividing the *cube* of Saturn's distance of 893,955,000 miles by the *cube* of the 487,491,000 miles of Jupiter's distance.

"In like manner, the periodic times of Jupiter's third and fourth satellite round Jupiter are $7\frac{154}{1000}$ days, and $16\frac{688}{1000}$ days; the squares of these numbers are $51\frac{187}{1000}$ and $278\frac{515}{1000}$. Their mean distances from Jupiter are 670,080 miles, and 1,178,560 miles; the cubes of these numbers are 300,866 (12 ciphers,) and 1,637,029 (12 ciphers,) and the proportion of 51.187 to 278.515 is almost exactly the same as the proportion of 300,866 to 1,637,029."—*Airy's Gravitation*, p. 28.

THE SUN.

P We have seen (M, p. 18) that the parallax of an object is less as the distance of that object from the station of the observer is greater; and that the distance and magnitude of our nearest neighbour, the moon, might be determined from the difference of her apparent places in the concave sphere of fixed stars, if viewed, at the same time, by one person who has her in his horizon, and by another who has her in his zenith, and to whom, therefore, she appears to be situated amongst the stars as if viewed from the earth's centre.

On the same principles, (see H, p. 19,) (as well as by processes founded upon principles more involved and refined,) the distance and magnitude of the sun have been ascertained. He differs but little from the moon in the apparent dimensions of his disk; but whilst the moon's displacement arising from this difference of the situations of view amounts to nearly a whole degree (3,600 seconds), the sun's parallactic displacement amounts only to 8½ seconds.* The sine of this minute angle is little more than the 24,000th part of the radius of the circumference on which it is measured; and, hence, the 4,000 miles of our terrestrial semi-diameter must be multiplied by 24,000, to shew us the distance of the sun. Now 4,000 × 24,000= 96 millions† of miles; which is 400 times the distance of the moon.

Q It is plain that an object appearing of the same diameter as another object when situated at 400 times its distance, must in reality be 400 times as wide: hence the sun's diameter is to that of the moon as 400 to 1; and, since the bulks of spheres are in the ratio of the cubes of their diameters, we must cube this 400; thus (400 × 400 × 400= 64 millions) is the bulk of the sun when compared with that of the moon as expressed by 1. It will help our conceptions of this enormous bulk, if we suppose the centre of the sun to be placed where the centre of the earth now is, and recollect that the body of the sun would extend on all sides to double the distance of the moon nearly!

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* That is to say, whilst the semi-diameter of our earth is equal to the sine of nearly a degree on a circumference drawn from the moon as a centre, and passing through us, (P, p. 19,) that same semi-diameter will be the sine of an angle of not more than 8½ seconds of a degree, on a circumference so large as that passing through us and centering in the sun.

† The true average distance, as found by other means, is 95 millions of miles.

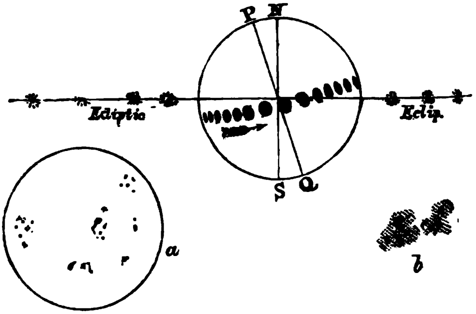
SOLAR SPOTS. DIRECTION AND RATE OF THE SUN'S ROTATION.

R The first astronomical notice of the Solar spots is said to have been made by our countryman, Harriot, a mathematician contemporary with Galileo of Florence, the inventor, or first promoter, of the telescope. The larger of these spots may, however, sometimes be seen in damp foggy weather by the unassisted sight. A telescope of low power, with a darkened glass, will always suffice to reveal them; and by shewing their progress across the sun's disk, day by day, will enable the pupil to watch the direction in which that great globe rotates, and that also in which his attendant planets and their moons revolve about their axes and in their orbits, and thus direct and simplify his conceptions on this subject.

These travelling spots which, when more minutely viewed, have the appearance of ink-blots surrounded with a stain, frequently change their forms; their clusters at one time appearing to accumulate and condense, and at another time to break up and become dissipated.

S Sir William Herschel regarded them as openings in the outer self-luminous atmosphere of the sun, through the middle of which we see his dark body, whilst a cloudy stratum more immediately underneath this outer self-luminous atmosphere is seen reflecting its light from above. We are thus to consider the central and darker portion of such a spot, to be the laying bare of the Solar body itself by the removal of both coverings ; but the penumbral edge, or stain, to be the exposure of its inner covering only.

Openings are occasionally seen with diameters twenty of which would equal the sun's diameter ; and which, consequently, are 5½ times the width of our earth ; yet the greatest of these wonderful chasms generally closes and disappears in the course of six weeks.



P and Q represent* the situations of the poles of the sun's axis, as deduced from the apparent path of a spot. N and S, the points at right angles with our ecliptic. The arrow on the disk gives the direction of a spot, the foreshortening of which, as it advances and retires, being represented by the *exaggerated* blots above it ; (*a*) fairly represents a view of the sun's disk as it may sometimes be seen through a small telescope ; (*b*) is a magnified representation of a cluster, such as one of those given on the left hand disk.

T In describing the direction of the progress which these spots make around the sun's axis, we may notice,

1st. It is, like the direction of our own motions and of those of every planet and satellite, that of the pen in forming the letter O in common penmanship ; viz. from the left hand to the right, as *we* look at his disk who dwell in high northern latitude.

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* The inclination of the line P Q, is necessarily exaggerated to render it evident in a drawing like the present.

2dly. These spots appear to move at first slowly on the left (or east) "limb" of the disk, but gradually quicken their apparent rate of progress until they arrive at the middle region; whence they again proceed with a retarded motion until their disappearance on the right. This, as well as their fore-shortened forms on the left and right, is what might have been expected from the globular figure of the sun's body.—(*See the Diagram*).

3dly. They do not move parallel with that line of stars which the sun appears to go over in the course of our year, viz. the stars which are in the same plane with our path around him, and which therefore, are said to be "in the ecliptic." Hence, the axis on which the sun turns is, like our own axis, not perpendicular to the plane of the ecliptic, but must be inclined to it as the paths of these several spots are inclined, viz. 7° 20′.—(*See the Diagram.*)

4thly. These spots are somewhat less than a fortnight in passing from the left (or east) "limb" to the right (or west) "limb" of the sun; performing their whole *apparent* revolution (behind and in front of him) in twenty-seven days. If, for instance, the time be marked at which a spot of peculiar form reaches the centre of the disk, as seen from the earth on a certain day, it may be recognised as occupying the same situation again at the completion of twenty-seven days; but since our earth, during that time, will have performed about 27° of its own path around the sun in the same direction, that spot (or rather the sun which bears it) must have fulfilled not only the 360° of its rotation, but, additionally, those 27°, in order that it should overtake us and be thus exactly opposite to us again. The sun, therefore, during these 27 days must have turned 387°; and by the common "Rule of Three," must have turned its 360°, or made its exact rotation, in about 25 days only.

THE PLANETS, AS VIEWED FROM THE CENTRE OF THE SUN.*

V If you were placed, ***head northward***, at the centre of the sun's mass, with its body and luminous atmosphere revolving about you whilst thus yourself without motion,† it is evident that the wondrous phenomena just described (p. 240) would continually be moving from your right-hand towards your left; and if, when so situated, your vision were telescopic, and your capability of observation such as to correspond with circumstances so extraordinary, you would see our little globe and its fellow planets, together with their satellites, all holding their courses around you in the same direction as those spots, and over lines of fixed stars which might direct you in mapping down their several orbits for *us*; because the stars, as seen by you, would differ in no perceptible degree from their present relative positions and magnitudes on *our* celestial sphere: the line of your distance from us, of 95 millions of miles, being utterly insignificant when contrasted with theirs, and your wonderful observatory and our own, with respect to them, being thus fairly considered as *adjacent*.—*See Illustration*, G, on p. 4.

W From our ever-shifting earth the paths of most of the *planets* often appear to be in "looped curves," devious and mazy; and a long and laborious consideration of circumstances is requisite to unfold the real simplicity of their arrangements and motions; but from your solar observatory all would be seen in beautiful order and harmony.

We may suppose that you would naturally be led to refer the various motions visible from your sun-centre to the circular lines in which the solar spots would be moving around you. Now these move, like the several parts of the surface of the sun, and like the knots in the rope of our young friend skipping, (p. 100,) with velocities varying, not with their distances from you at the centre, for they are all alike distant from you; but varying with their several distances from their centres of motion in the solar axis; hence the course of the swiftest of them would point out to you the Solar *Equator;* and this, or rather the line of stars seen in the same plane with it, might be taken for your standard circle in the heavens, and to it you might refer the orbitual paths of the planets.

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* For the convenience of illustration, Ferguson has supposed the sun to be transparent, and an observer to be furnished with the means of existing within it, and even of recording his observations! We must hope to be forgiven even for extending so extravagant an idea as this.

† The sun's mass is agitated about the common centre of gravity of the sun and planets; hence its centre has some motion, but for the sake of simplicity it is disregarded here.

X But probably you might still so feel interested in *us* as to retain our orbit for your standard, and even continue to reckon from our first point of Aries "for auld lang syne." The crossings of the several planetary tracks through the ecliptic or plane of our orbit, are what we call their "nodes." It is evident that in the case of bodies so near as those of our system, their longitudes as seen by you whilst crossing our plane, differ considerably from those points or longitudes at which *we* see them to be crossing it. Astronomers, however, reckon with *you;* and the point (marked in degrees and minutes from 1° of Aries) at which *you* would see a planet crossing our ecliptic to go northward or southward of it, is the "longitude of its ascending or descending node." In the same manner, as your minute observation compared the periodical variations in the apparent size and brilliance of any one of these bodies, you would judge that they occurred as it approached the points of its greatest and least distance from your illuminating station; and you might record the longitudes of these unvarying[*] points—the *perihelion* and *aphelion* of the planet's orbit.

Y The "latitude" also, of these bodies. we refer to our ecliptic plane; and the greatest number of degrees of distance from our plane to which any one of them attained as seen from your observatory, would give you the inclination of its path to our ecliptic.

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[*] *i. e.* not perceptibly varying in the short period of a human life. (See X, p. 259.)

It is evident that, as their residences so revolved around you, the inhabitants of these several little globes must behold your fixed solar station appearing to move in the same direction in the opposite portions of their several ecliptic circles, and that too with angular motions (p. 100) in those several circles, exactly corresponding with their own.

Not one of these planets and satellites would "wax and wane;" nor would the tail of a comet, even like that of 1680, be visible, although extending over 70° of *our* heavens; for your dwelling-place being the source of their borrowed light, their whole reflecting faces would of course always be presented to you.

Z You would, we suppose, most naturally measure *time* by the period of the sun's rotation. By attentive consideration of a whole series of observations during very many of these, and thus comparing the several periods in which these several bodies completed their orbits; and remarking that no one of them moved uniformly, but that, as each of them became periodically brighter its motion was accelerated; and that it was retarded also in the opposite and less splendid portion of its path; you might not only infer that those which completed their orbits in shorter times, moved in more circumscribed paths, and consequently were nearer than those which made the slower circuits; but that their movements, as well as their light, were in some way connected with your solar dwelling-place, and even mysteriously dependent upon it.

Sometimes indeed, an undefined cometary body would approach so near, and so rapidly, as to exhibit a most remarkable contrast in its brilliancy and dimensions; and be the occasion perhaps, even of perturbation to your sunny thoughts; but the *apparent* path even of this would be circular, whilst its form, so rapidly enlarged, as rapidly died away into invisibility.

B Jupiter's superior distinctness and brilliance, compared even with Mercury's, might at first induce you to think that he was the nearest of all the planets, except perhaps Venus; but a comparison of their periods would correct this idea, whilst it led to the consideration of his great distance and superior dimensions; as you would perceive that whilst Jupiter performed *one* revolution, Mercury performed *fifty*, Venus *twenty*, the Earth *twelve*, and Mars *nearly six and a half*, revolutions.* Beyond this, however, your ingenuity would fail you for want of *data* :—your position at the centre of our system is disadvantageous, except for the general survey just described.

If imagination, having placed you in the sun, and having also rendered its opaque body and luminous atmosphere alike subservient to you, can suppose you furnished with some means of communication with an astronomizing inhabitant stationed at its northern *pole*, we know that, comparing *his* map of the orbits, (for instance, of Mercury, Venus, and the Earth,) with your own taken from the sun's centre, you would find that observation at his distant station, (440,000 miles from your central one,) had displaced, by *depressing*† their paths in the sky, but each to a different amount; and Venus's depression, so caused, being greater than that of the Earth and less than that of Mercury, you might more certainly infer that Mercury was nearer, and the Earth more distant than Venus, &c.

Such are the faculties with which the great Author of his being has invested man that, even in his far-fallen condition, exercised by the very inconveniences attendant on that condition, he has been enabled, not only to understand much concerning the circumstances connected with the motions, and magnitudes, and distances, of these planetary bodies, but also to calculate and predict them with the greatest precision, for distant periods of time. And a handful of sand from the shore, and a weed from the neighbouring rock, furnish him with materials which he has learned to transmute and to model, so as not only to reveal to his gaze much of "the vast and the minute" of the system to which his own little dwelling-place belongs, but the kindred motions of distant systems of circling though centering suns;‡ and far beyond even them, the light of numerous other firmaments,* each of them, in all probability, crowded with the witnesses of his Maker's beneficence and power!

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* Saturn, on the contrary, during *one* revolution of Jupiter, would not get through nearly *one half* of his orbit, and Uranus *not one seventh* of his.

† See Parallax. ‡ See Double Stars (Index).

Reasons for supposing that the Planets are inhabited.

1. Their similarity of form to each other and to our world—the globular figure being that which affords more surface than any other figure for the residence of contemplative beings:—And the amount itself of their surfaces, which even if, like that of our own earth, habitable only on one fourth part, would accommodate 400 times as many such individuals.

2. They are opaque and solid bodies:—Opaque, from the manner in which their shadows are cast, and from the manner in which they receive shadows: solid, from the manner in which their motions are performed, and from the several attractions which their masses exert on the sun and on each other.

3. The *extent* of animal existence as revealed by the microscope:—Organic life being discovered wherever there is a superfluity† for its sustenance, at least on the *surface* of our globe (see pp. 7 and 8).

4. Their several annual and diurnal revolutions:—One common law regulating their motions in their orbits to produce, in exact times, the interchange of seasons; and the rotation of each about its axis, providing for the alter-

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* See definitions *Nebula* and *Galaxy* (page 54).

† It is not correct that "every drop of water teems with life":—no microscope can detect animalcules in fresh spring water. The author has, however, frequently seen, at least many hundreds *for a moment* "at liberty" in so small a portion of moisture as he has *wiped* on to a piece of glass from the end of a fine needle, which he had dipped into stagnant water and afterwards shaken to throw away its *drop*:—the next moment shewing only the confused forms of those animalcules, all crushed by the access of atmospheric pressure, in consequence of their film of *element* having evaporated and thus left them exposed.

nate enjoyment of the solar radiance, and the splendours of night.

5. These globular surfaces are diversified with hills and valleys, and are thus fitted, as far as human judgment is concerned, to afford at once greater extent and greater enjoyment:—The mountain eminences of the moon and Venus have been measured; and the manner of reflection of the sun's beams from the rest, indicates the inequalities of their surfaces (3 of M, p. 183).

6. The existence of their atmospheres:—Those of our moon and of Venus have been ascertained by Schroeter, the celebrated German astronomer, and the dull ruddy appearance of Mars is by many attributed to the peculiarities of his.

7. The provision made for a supply of light to them:—Mercury, the nearest of all the discovered planets to the sun, has his nights abundantly provided for in the reflecting disks of Venus and our earth; the former appearing, when nearest to him, nearly seven times as large as she does to us, and of much more intense brilliance; our earth too, with its circling satellite, affording him, periodically, a considerable quantity of light.

Of those beyond us, Mars, if he have not a satellite, may possess a compensation in the peculiar refractive power of his atmosphere. Jupiter, at his five-fold distance, has four moons; and Saturn, at a nine-fold distance, in addition to seven moons, has the wonderful reflecting surfaces of his rings. Uranus, at double Saturn's distance, although very inferior in size to Saturn has, as if in consequence of that remoteness, six tributary satellites. (See also the note in italic, p. 161.)

C "This fact at least, seems to be philosophically certain, that all the bodies which compose our planetary system must have been placed *at one and the same time*, in that arrangement, and in those positions in which we now behold them; because all maintain their present stations and motions and distances, by their mutual action on each other; neither could be where it is, nor move as it does, nor subsist as we see it, unless they were all co-existing; the presence of each is essential to the system which they constitute—the sun to them, they to the sun, and all to each other. * * * * Each of the planets and the sun have, no doubt, their several peculiar uses; but they have also been fabricated with mutual relations and for common purposes."—*Sharon Turner.*

"Thus saith the LORD THAT CREATED THE HEAVENS: God himself that formed the earth and made it; He hath established it, He created it not in vain, He formed it to be inhabited: I am the LORD and there is none else."—*Isaiah* xlv. 18.

THE PLANETS.

JUPITER. HIS DISTANCE, BRIGHTNESS, BULK, MASS, SPECIFIC GRAVITY, FORM, ROTATION, BELTS, YEAR, ETC.

D Jupiter, although distant from the sun more than 500 millions of our miles, is the largest of the planets, and contains nearly 340 times* as much matter as is contained in our earth. The phenomena he presents in the revolutions and perturbations of his beautiful miniature system, are so useful in illustration of the changes which take place in the whole system connected with our sun, that it will be advantageous to consider him first, and more at length.

When nearest, his distance from us is more than 400 millions of miles; but even when we have removed nearly to the other side of the sun with regard to him, and are consequently 190 millions of miles farther from him, his brightness is inferior only to that of our neighbour, Venus. This is attributable chiefly to his great bulk; his diameter being eleven times that of the earth, and therefore presenting a reflecting disk 121 times (G, p. 15) that which our earth or Venus (nearly our equal) would present at his distance.

F The compression of Jupiter's spheroid is very observable, even with a telescope of moderate power. His oblateness is not less than one fourteenth; his polar diameter or axis, being 6000 miles less than his equatorial diameter, because his mass is most spread out "where the whirling motion is most rapid, that is, at his equator." Now it has been discovered, by attentively watching spots occasionally seen on his disk, that the rotation of his huge body takes place in less than ten hours.† "This forms a most satisfactory comment on the reasoning by which the spheroidal figure of the earth has been deduced from its diurnal rotation.* * * * And to confirm, in the strongest manner, the truth of these principles * * * and fully to authorize their extension to this remote system, it appears on calculation, that this (viz. one fourteenth) is really the degree of oblateness which corresponds, on those principles, to the dimensions of Jupiter and to the time of his rotation."—*Sir John Herschel.*

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* Cubing 11, Jupiter's diameter, we find that his relative *bulk* (1 of F, p. 168) is 1330 times that of our globe. If we divide this number by 340, (relatively representing his *mass*,) we shall get the number 4, nearly, for his relative *density*; that is, a cubical foot of Jupiter contains only about one fourth of the matter contained in a cubical foot of *Earth*; or would weigh *here* only a quarter as much, nearly.

† Nine hours, fifty-five minutes, fifty seconds.

G As the "equator" and "parallels of latitude" on Jupiter's globular surface, are thus eleven times as extensive as those which correspond to them on our earth, and as he is being carried about his axis in a period nearly twice and a half less, his inhabitants, in any given latitude, will move at a rate nearly twenty-eight times† that of the inhabitants of any corresponding latitude on the earth's surface. Let the pupil take this fact into connexion with the appearances of his disk:—In clear weather, a good astronomical telescope will always shew two or three cloudy streaks, well defined, crossing in the exact direction of his longer or equatorial diameter.

H The difference of intensity of the solar heat, as received by our equatorial regions, and those of our north and south, combined with the disparity of the motions of these several regions as our earth rotates with its atmospheric covering, produces most important results in the economy of our winds. (See "Trade Winds" Problem, Sect. III.)

"The *parallelism* of Jupiter's belts to his equator, their occasional variations, and the appearances of spots seen upon them, render it extremely probable that they subsist in the atmosphere of the planet, forming tracts of comparatively clear sky, determined by currents analogous to our trade-winds, but of a much more steady and decided character, as might indeed be expected from the immense velocity of his rotation."—*Sir John Herschel.*

K We have mentioned in another place, (p. 236,) the exact length of Jupiter's year. Had his axis been, like

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[*] See T, p. 228.

[†] $11 \times 2\frac{1}{2} = 27\frac{1}{2}$.

that of our earth, considerably inclined to the plane of his orbit, a large region on his very extensive surface would have been hidden from the sun during his half-year (six of our years). But the Creator has provided against this, by rendering his axis almost perpendicular to that plane.

JUPITER'S SATELLITES, THEIR MOTIONS AND PERTURBATIONS.

Jupiter has four moons, which revolve around him in the same manner as our moon revolves round the earth. The plane of our earth's orbit is so nearly level with the planes of the orbits they perform around him, that they appear to oscillate backward and forward almost in straight lines, often crossing his disk, and often disappearing behind him.

" The operation of their reciprocal attraction renders all the planets, and the great sun himself, constantly subject to disturbances;" " each makes small and transient deviations, now on one side of its path, and now on another, whilst the ellipse itself in which it is moving, is slowly, but perpetually changing both in form and position."—*Mrs. Somerville.*

Still, " the disturbing forces of the other planets are so small, in comparison with the attraction of the sun,* * * * that except for the moon and the other satellites, it is only by accurate observation, continued for some years, that the effects of perturbation can be made sensible."

" But Jupiter's satellites disturb* each other's motions to an amount, and in a manner, of which there is no other example in the solar system; and their motions are affected in a most remarkable degree by the shape of Jupiter."—*Professor Airy's Gravitation*, p. 110.

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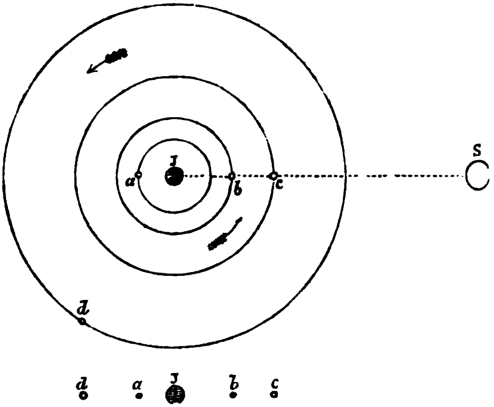
* The perturbations of these satellites, and the influence of Jupiter's mass and form upon them, have led to the determination of their masses. The *first*, or nearest, is a little larger than our moon, its diameter being 2,508 miles; the diameter of the *second* is 2,068 only; the *third* is a little larger than the planet Mercury, having a diameter of 3,377 miles; the *fourth*, or that most distant from Jupiter, is second in size, or 2,890 miles in diameter.



These orbits have but very little excentricity, and a faithful representation of them, or indeed of those of any of the planets, even on a larger scale, will not convey the impression of their being otherwise than circular.

Let J be Jupiter, centering the orbits of his satellites (V, on page 23); let (a) be the nearest or first satellite; (b) the second satellite; (c) the third, and (d) the fourth (their relative distances from their primary being nearly such as are shewn in the diagram). Whilst (b) and (c) are situated as drawn, J sees (b) in conjunction with (c) and with (S) the sun.* Here, whilst J's attraction is such as to keep (b) and (c) in their orbits, J itself being attracted by S (the sun) and retained by it in his own orbit, must additionally be affected, and therefore disturbed, by (b) and (c); and each of them, in thus disturbing its primary, on whose every motion it is dependent, is likewise disturbing *itself* and its fellow satellites; (b) tending to pull (c) *towards* J, and (c) pulling (b) *from* him. Meanwhile, (d) is influencing both (b) and (c) in proportion to its mass, and to the squares of their several distances from it,—the effect of (d) on them being evidently that of retardation; whilst they, in like manner, severally accelerate her. All three of these are operating on distant (a); (d) *accelerating* (a's) progress, and (a) in proportion to its mass and the square of its distance, *retarding* (d), and investing her with a greater retarding influence on (b) and (c). All this time they are, none of them, unaffected by the sun.

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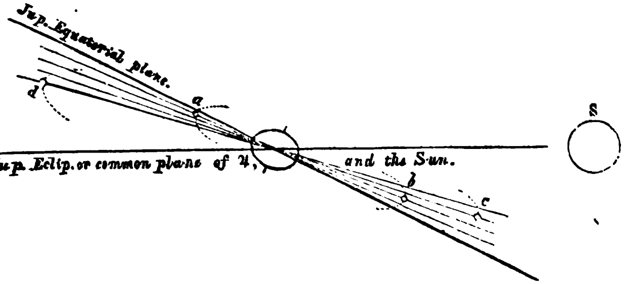
* The young reader must observe, on page 195, why some inhabitants of J may not see these satellites eclipsing the sun.

“ Let us now take a view *in section*, of Jupiter, the plane of Jupiter's own orbit, and the planes in which these satellites revolve around him, and we shall understand that these satellites are disturbed in *latitude* besides being (as just seen) disturbed in *longitude*.



If Jupiter were perfectly spherical, his direct attractive influence on these satellites, would be such as if all his matter were stationed at his centre. (See p. 218.) Even then, however, their mutual disturbances would be not only such as were just now described when we were looking down upon the planes of their several orbits : *Because the planes* of their orbits do not *coincide*, these satellites *act upon each other to alter their several inclinations* (see figure) ; that moving in the plane most inclined to the plane of Jupiter's equator, (as *d* the 4th,) operating to drag *upward* or *downward*, according to its position in its orbit, the others (*a*, *b*, and *c*,) less inclined, as they, at the same time, are similarly acting upon (*d*) ; whilst *the distant sun is operating on all of them*, as each, in its several alternations, is above or below the plane of Jupiter's own orbit about the sun, *to bring them all into the plane of that orbit*. But as Jupiter's spheroid is so very oblate, " the *irregularity* of attraction" produced by the protuberant matter in that planet's equatorial regions is always " pulling" the satellites towards the plane of his equator :—Hence, from this complication of disturbing forces, " the position of each of the planes in which the four satellites are revolving, is to be determined by the consideration that the satellite in that plane is drawn —towards the plane of Jupiter's orbit by the sun's disturbing force— towards the plane of Jupiter's equator by the force depending on Jupiter's shape—and towards the plane of each of the other three satellites by the disturbing force produced by each satellite — and these forces must balance in the long run." — Professor Airy *on Gravitation*, p. 191.

N So great is the effect of Jupiter's shape, that the orbits of the three interior satellites, although differing among themselves, have very little inclination to the plane of his equator: the fourth satellite, which is much more considerably removed from the primary, and thus much less affected by his shape, has the inclination of his orbit nearly *fivefold* that of the third.

P The principal results of those disturbances in the *Jovial* System which take place in consequence of the satellites revolving thus, in different periods, in planes of differing inclinations, and around a body having its mass arranged into such a form, are very instructive to the pupil,—viz. the slow but constant shiftings of the *nodes*, or intersecting points of their orbitual planes; and the changes too of their *apses*, or of those parts of their several elliptical orbits in which they are nearest or farthest from Jupiter (their places of *perijove* or *apojove*).

The "inequalities of the motions of Jupiter's satellites * * * are so much connected, and (as we may say) so completely entangled, that though they may be explained" * * (in the popular manner so delightfully exhibited in the professor's book) * * "it would hardly be possible to calculate them in that way. A mathematical process of the most abstruse kind, which will at the same time embrace the motions of all, is alone competent to this object."—*Gravitation*, p. 138.

Q So completely are these motions, with all their perturbations, thus "embraced" in the present calculations of astronomy, that the mariner leaves Europe in 1840 with his cabin shelf provided with an Almanac for 1843, on the latest columns of which he may depend, even to a *tenth of a second* of time, for the instant of the immersion or emersion of one of these minute bodies: in order, with corresponding exactness, to record his longitude on the shore of a newly discovered island in the vast Pacific!

Discovery of the Velocity of Light.

R The discovery of the velocity of light is chiefly attributable to observations on the satellites of Jupiter, at the constantly varying mutual distances of that planet and our station, the Earth. When Jupiter is in opposition, (that is, when he appears on our meridian at midnight; the sun being under the north point of our horizon whilst we are looking at Jupiter elevated in the south,) the situation of our planet in space is, of course, exactly between the sun and Jupiter: we are then, consequently, nearer to him by the whole-width of our orbit (190 millions of miles) than when, after somewhat more than six months, we have so outstripped him in angular motion as to be on the other side of the sun with respect to him.

It was found, (as early as 1675,*) that the *times* calculated for the occurrences of eclipse, &c., of the satellites, were too early in the former case, but too late in proportion as the Earth passed from an average distance into the latter circumstances;† and putting the facts together, the conclusion was attained, that the light reflected from these bodies to reveal their phenomena to our eyes, occupies 16 minutes, $26\frac{6}{10}$ seconds in travelling across a space equal to the diameter of our orbit; or double our distance from the sun! Fifty years afterwards, Dr. Bradley (English Astronomer Royal) confirmed this by calculations founded on a most refined discovery of apparent displacements of the fixed stars.‡

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* By Römer, a Danish astronomer, then resident in Paris.

† Jupiter, and especially the phenomena of his satellites, (see Note preceding the Rule, on p. 157,) cannot be satisfactorily observed unless at a considerable angular distance from the sun; but the computation may be supposed to have been made for Jupiter's average distance.

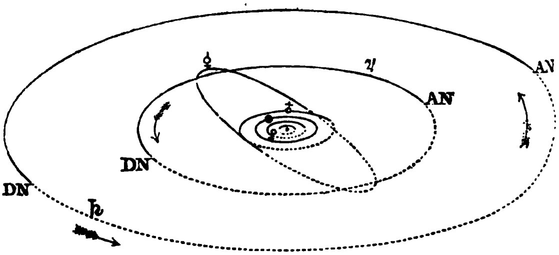
‡ See Aberration (under a short notice of *the Earth* as a planet) in the pages following.

THE SYSTEM GENERALLY.

DISTURBANCES.

The pupil is now somewhat better prepared to survey the planes of the several orbits of the whole system; and, in some degree, to appreciate the labours of the scientific astronomer. We must be allowed to remind him, however, that the circumference of a shilling, placed at the middle of a table in a large room, represents fairly the orbitual path even of Uranus; the distant walls of the room being supposed to be the situations of some of the nearest fixed stars!

The diagram now introduced extends only to the orbit of Saturn: the orbit of Uranus would have required double space. The plane of the earth's orbit (our ecliptic) is that to which the others are to be referred (p. 243). It will be seen that, accordingly, the marking of this is uniformly black; the more conspicuous portions of the orbits of each of the other planets being those halves of them which are above, or north of our ecliptic plane; and the less conspicuous portions, those *below* it. The symbols point out the supposed places of the planets, and A N, and D N, their *ascending* and *descending* nodes.



In the pages which immediately follow the present article, the masses, distances, periods, &c., of the planets are briefly particularised.

*** It is of much importance to remember that the attracting force exercised by any mass, is the same on a greater as on a less body, provided their distances from it be the same. It is that *inequality* between the two attractions of a planet for another planet and for the sun, which is as constantly varying in its degree and in its direction as the relative positions and distances of the three bodies are varying, that is the cause of perturbation.

Let the pupil bear in mind what has been attended to in the diagrams illustrating Jupiter's system, and he will easily conceive, from the positions marked above, that as ♄, at the time supposed, occupies a place in his orbit which is not only in advance of ♃, but also somewhat southward of him, ♄'s tendency on ♃ is to *accelerate*[*] and *depress* him, as that of ♃ is to *retard* and to *elevate* ♄.—♃'s influence on ♂ and ⊖ is to retard them, and pull them upward; but whilst retarding ♀, to *depress* her. So on, with regard to the influences of the rest.

[S] The mass of Jupiter is equal to 300 *Earths*, and that of Saturn to 100 of them. Hence, it may be conceived that the perturbations they occasion are most conspicuous. Even Mercury, whose distance from the sun is not *one-thirteenth* of that of Jupiter, is so affected as that its orbit is "flattened a little on the sides nearest to, and farthest from Jupiter;"[†] and Venus, the Earth, and Mars, all likewise *interior* with respect to him, have their apses (or points of perihelion and aphelion) progressing or regressing; and their orbits a little more or a little less excentric, according as Jupiter comes more nearly into a line with their apses, or into a position at right angles to them. The inequalities resulting from the mutual action of Jupiter and Saturn were palpable enough to be much earlier known to astronomers.

[T] "When the action and reaction of the whole system is taken into account, every planet is acted upon, and does itself act, in this manner on all the others; and the joint effect keeps the inclinations and excentricities (*see our p.* 23) in a state of perpetual variation. It makes the major axes (*see p.* 23) of all the orbits continually revolve, and causes, on an average, a retrograde motion of the nodes of each orbit upon every other."—*Connexion of Physical Sciences*, p. 25.

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[*] A disturbing force acting in the direction in which the planet is already moving, and, therefore accelerating at the instant, has the reverse effect "in the long run," for it increases the size of the orbit, and thus *lengthens* the whole time of revolution. On the contrary, a force opposing the planet's motion, and thus retarding it for a time, makes the planet's whole revolution shorter by contracting the dimensions of its orbit.

[†] Airy's *Gravitation*, p. 140.

"When the existence of perturbations was revealed, NEWTON himself feared the instability of our scheme, and imagined that the Deity must directly interfere to preserve it. Groundless fancy! The Deity is no limited or imperfect architect. His thought, which comprehends the universe and all its destinies, is stamped upon its minutest part!"—Nichol's *Phenomena of the Solar System*, p. 231.

W The inequalities of motion which more immediately occur from the perturbing action of the planets on each other, are called *periodical*, because they are compensated when the revolving bodies return to the same relative positions in their orbits; although several hundreds of years are, in some instances, required even for this. But changes result in the *elements* of the system, which require *ages* to render them palpable in their inequalities; and such inequalities are, therefore, termed *secular* (seculum *an age*). The shiftings of nodes, or places of the intersection of the planes of the orbits, (such as A N and D N,) are important secular variations. The nodes of Jupiter's orbit from the action of Saturn alone require 36,261 years to accomplish their revolution.

"*Secular* inequalities are, in fact, nothing but what remains after the mutual destruction of a much larger amount (as it very often is) of *periodical* * * * * The varied orbit accommodates and adjusts itself to the average of these* excursions on either side of it; and thus continues to present, for a succession of indefinite ages, a kind of medium picture of all that the planet has been doing in their lapse, in which the expression and character is preserved, but the individual features are merged and lost."—*Sir John Herschel's Astronomy*, p. 342.

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* That is, the *periodical inequalities*.

"The task of carrying order and law into this mass of apparent confusion, has required a long series of men of transcendant intellectual powers, and a perseverance and delicacy of observation, such as we have not the smallest example of in any other subject."—*Whewell's Inductive Sciences*, Vol. II. p. 221.

x "It was, perhaps, the grandest discovery of the late generation, that these perturbations are *Oscillatory*—that a planet, after leaving its regular or mean path for a certain time, returns slowly to that path, deviates from it on the other side, and again returns and passes to its former limit. Like a pendulum these bodies move, now to one side of their mean line, now to the other; and although the oscillations in some cases occupy countless centuries, they are not less sure* and fixed than those of the rod whose regulated motion marks a second of time. How striking is this new proof of the beauty and perfection of our little home-system! How reverentially have we been cared for!" —*Professor Nichol.*

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* Lagrange and Laplace have demonstrated that "the arrangements of the Solar System are stable—that, in the long run, the orbits and motions remained unchanged. * * * The perpetual perturbations reach a maximum value and then diminish. The periods which this restoration requires are, for the most part, enormous. * * * But the restoration is, in the sequel, as complete as the derangement; and, in the mean time, the disturbance never attains a sufficient amount seriously to alter the adaptations of the system."—*Whewell's Bridgewater Treatise*, p. 162.

TELESCOPIC VIEW OF THE PLANETS.

We shall endeavour to introduce a few such particulars respecting the distant planets, as may best answer the enquiries generally made in looking at them through the telescope, reserving a description of the moon for those pages in which the problems are introduced which relate to her. We first notice the following :—

1. The *Bulks* of the planets have been ascertained by comparing their apparent dimensions with their distances, as found by parallax.

2. The *Masses* of such planets as have not satellites, have been ascertained from the quantity of disturbance they create in the system —the masses of those that have satellites have been found, too, from the motions of those satellites—the masses of the satellites themselves, like those of the unattended planets, from their mutual perturbations.

3. The *Mean Density* of a planet (that is, how much of its matter, as compared with that of *earth*, is contained in a cubic foot, mile, &c.) is found by dividing its bulk by its mass. Thus, Saturn's bulk is 990 times that of the earth; but its mass only 95 times. Dividing the one by the other, we obtain nearly 10½, for the comparative *porosity** of that planet. Hence the material of which Saturn is made is about *half* as heavy as water, our earth being on an average about *five times* as heavy as that fluid.†

4. *Weight* on any planet, or the whole attractive force of its mass, (considered as globular,) is that which is found, not only by considering its mass, but considering also *the square of the distance of its centre* (T, p. 218). Thus, if Jupiter had his 300-fold mass condensed into as small a compass as the bulk of our earth, weight on his surface would evidently be 300 times as great as weight *here;* but, inasmuch as the distance of his centre is 11 *times* as great, we must diminish this 300-fold weight 121 *times*, and this reduces it to a weight of 2½ only.

5. In considering our earth's rotation, and the pendulum, &c., (page 228,) we noticed that a portion of weight is counteracted by centrifugal force, especially near the equator. The rapid rotations of the huge bodies of Jupiter and Saturn, furnish a considerable

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* Perhaps the molecules of matter may themselves be different in the *quantity* they contain.

† "If an ocean of water were poured into the cavities upon the surface of Saturn, its equilibrium would not be stable. It would leave its bed on one side of the globe, and the planet would finally be composed of one hemisphere of water and one of land."—*Whewell's Bridgewater Treatise*, p. 180.

counteraction to *weight* on their surfaces. Still, so great is attraction at their surfaces, that the rising force of the sap in vegetation, animal muscular power, the strength of fibre and of bone, and the state of all the circumstances of adaptation *here*, would evidently be all unequal to their burthens *there*. On the smaller planets, as on Mars or Mercury, the inhabitants would be equally inconvenienced from the excess of such supplies.

6. *Our* circumstances, although circumstances of mercy, are those of penalty and of trial; *theirs* cannot be unhappy, or uneasy, if still keeping "their first estate!"

SATURN.

Next to Jupiter, whose system we have more fully considered in illustration, Saturn is the largest of the planets.

The wondrous appendage of his rings is totally different from anything else in the Solar system. The *flat* of the two rings is a little more than thirty-three thousand miles across, whilst their thickness is not more than *one hundred* miles. They are kept at a distance from the attracting planet they surround by centrifugal force; and it has been ascertained that, accordingly, they revolve about Saturn in ten hours and a half, *i. e.* in the time that a satellite at their little distance of 22,000 miles from so large a primary must have revolved to balance his attraction (p. 231).

The Earth is never quite so much as 29° to the north or south of the plane of these rings, and as they are concentric, and in the same plane with each other, their united appearance is generally that of a long ellipse; the interval between the interior one and Saturn being easily seen on each side of him, but the mark of their separation from each other being but very dimly discerned,* except in very large first-rate instruments. A smaller telescope, with a power of 20, may suffice to shew that Saturn's whole form is not round. It was because the early uncorrected (C, p. 15) telescopes shewed the extremities of his outer ring as protuberances on each side of the disk, whilst they did not distinguish the intervening portion and its shadow on the planet, that the astronomers who first thus viewed Saturn described him as having *ansæ*, (or handles,) like a vase.

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* An achromatic telescope of 3½ feet focus is the smallest that can be advantageously employed for astronomical observations. The author's telescope, a refractor of this size, described by its maker, the late well-known Mr. Tulley, as "a very perfect instrument," and which shews some of the more difficult of the double stars, shewed the division between Saturn's ring rather indistinctly, even when Saturn's declination was more favourable for a view of him in our latitude than it has lately been.

Of Saturn's seven satellites, the largest is about the size of Mars; two of them, at most, are ordinarily perceptible in a moderate astronomical telescope, and five in the largest and best. His other satellites skirt the edge of the outer ring, and are not at all visible, except when the rings, so inconsiderable in thickness, disappear in consequence of the earth's getting into their plane; or when Saturn is so situated with respect to the sun, that he can enlighten only the edge of it. In October, 1832, and April, 1833, the rings were invisible from the former cause; in December, 1832, they were invisible from the latter. Last year (1840) the rings presented their most open appearance: in 1847 they will again disappear.

	MILES.	
Saturn's Diameter..	76,068	His mean Angular Diameter, as seen from the Earth....16"
His mean distance from the Sun ..	890,000,000	

The plane of Saturn's orbit crosses our Ecliptic plane with an inclination of 2° 30′, and his axis of rotation is inclined rather more than that of the Earth, or to nearly 30°.

	YRS.	DYS.	HRS.	MIN.	
Periodic time, or length of Year, performed with a velocity* of 6 miles per second................	29	175			His year containing *twenty-five* thousands of his days.
Rotation on Axis or length of day...............			10	16	

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* A portion of that wonder which impresses us when we first hear of the hourly rate of a planet's translation in its orbit, subsides when we take their bulks into consideration. The earth moves through 68 thousand miles per hour, but this is not nine times its diameter: and Saturn moves through 22 thousand miles per hour, not one-third of his. These would appear to be slow motions, if we could watch them as imitated in a planetarium the parts of which were constructed in exact proportions, and moving in times correctly related to those of the bodies they represent.

URANUS.

Uranus was not discovered to be a planet until 1781. It still bears the name of "Herschel" in honour of its discoverer, as well as that of "the Georgian," in honour of his patron George III. It is the most distant in the system, being nineteen times as far from the sun as the earth is.

The distance of Uranus is so great, that although next to Saturn in magnitude, his apparent diameter in our sky is only one fourth of that of Saturn, and the light he reflects so feeble, that his appearance, even in a good telescope, is rather that of a planetary nebula; only such telescopes as those of Herschel, or Struve, or Shroeter, can at all distinguish any of his moons. "Two undoubtedly exist, and four more have been suspected."* Sir John Herschel, as well as his father, their discoverer, has ascertained the remarkable fact, that unlike all other planetary motions of the solar system, that of the moons of Uranus is nearly at right angles to the planet's orbit, and retrograde.

The diameter of Uranus is 35,000 miles.
His mean distance from the sun 1,800,000,000 miles
His mean angular diameter, as seen from the earth, 4″.

The plane of his orbit, coinciding with our Ecliptic, except 0° 46′.
His periodic time or length of year, 84y. 29d.
His time of daily rotation, unknown.

THE EARTH.

Our planet, if viewed with a telescope at such distances as those at which we view Venus or Mars, would probably present a changing picture of the continents and islands (which occupy the fourth part of its surface),† with variable distinctness, according as the streaky currents of its atmosphere happened to be more or less loaded with vapour: the general serenity of its equatorial regions being marked by the more constant, but still broken, streaks[*] of the trade-wind regions a little north and south of it. The strongly reflecting snows of the Polar regions would render each of them also more or less conspicuous, for the alternate seasonal periods during which they are exposed to the sun or hidden from him.

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* Sir John Herschel.

† Only one twenty-seventh part of the land has a portion of land diametrically opposite to it on our globe.

From Venus, whose orbit is interior to our's, the earth (with the moon attendant upon it at an angular distance of about half a degree when most separated) would form a brilliant and beautiful object; our phases to Venus being, like those of Mars to us, variable only from the gibbous to the full.

But from Mars, since he is exterior, our disk would exhibit extreme phases, from the wiry crescent to the full, such as those we observe in Venus. Our moon, appearing sometimes to the right and sometimes to the left of our planet, but at its utmost remove being distant from it only about one third of a degree in his sky, and both occasionally crossing the sun as two black spots of very unequal magnitude. (*See Remark on Mars*, page 45.)

⁂ At the distance of Jupiter, our planet is probably involved in the sun's rays: and from Saturn even Jupiter (as Venus to us) is but a morning or evening attendant upon the Sun.

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[*] See H, p. 250.

[†] The Earth's southern hemisphere is presented to the sun seven days less than the northern one; but it receives, during this deficient period, an exactly equal supply of the sun's heat: for that which occasions the Earth's acceleration in our winter, viz. her lessened distance from the sun, exactly compensates for her more rapid passage through his beams of heat.

"Equal amounts of heat are received from the sun in passing over equal angles around it, in whatever part of the ellipse those angles may be situated."—*Sir J. Herschel.*

ABERRATION OF LIGHT.

B Our planet moves in its orbit at the rate of 19 miles per second:—light comes to us in its various directions from the heavenly bodies, at the rate of 190,000 miles in the same time. (*A ratio of ten thousand to one.*) Our motion, however, produces a slight change in the apparent places of the fixed stars, somewhat like the apparent alteration in the direction of a very distant ship's course, when we view it from the deck of a vessel itself in motion.

If the earth were stationary for a moment, in its orbitual *pathway*, the ray of a star would pass down the middle or axis of the telescope, and we should refer the star to the exact direction from which that ray reached the eye; but at the instant at which she resumed her course, it is plain that our telescope must be inclined a little, or that line of light would strike against its side; this would occasion a displacement, apparent in its amount and direction only to an observer provided with astronomical skill, and the nicest means of detecting it. The amount and direction of *aberration* depend upon the earth's situation at the time. When her motion is at right angles to the path of the visual ray, and its aberration is consequently greatest, it amounts only to 20¼ seconds of a degree.

Since the Earth is moving orbitually in a plane immediately *underneath* that point in the heavens which we call the pole of the Ecliptic, the amount of apparent displacement of a star situated *at* that point is daily the same, but constantly changing in direction; and it thus appears in the course of the year to describe a minute circle of 40½″ diameter around its true place. If, instead of being at the Ecliptic *pole*, the star (like *Regulus*) is situated in the Ecliptic *plane*, (the plane of our motion)—it appears, in the course of the year, to oscillate in a straight line to 20¼″ on each side of its true place. If neither in the Ecliptic nor at its pole, this displacement describes a minute yearly ellipse having its larger diameter 40½″, but more or less flattened; that is, less like a circle, and more like a straight line, in proportion as the star's latitude is less, or it is nearer to the Ecliptic.

Hence, since from this optical cause, the stars of various latitudes are *variously* affected, they are slightly displaced "*one among the other.*"

C The discovery of the aberration of light was due to the accuracy and sagacity of Dr. Bradley, in 1727, whilst unsuccessfully endeavouring to detect an annual parallax of the fixed stars (H, p. 277). The rate of the travelling of light, discovered fifty years before by Römer, (p. 255,) was fully confirmed by this discovery.

VENUS.

The Phosphor or Lucifer of the poets, when westward of the sun, and therefore preceding him as a *morning star* in the *East*—Hesperus or Vesper, when eastward of the sun, and therefore setting after him as an *evening star* in the *West*.

Venus differs but little in bulk from our earth; but as she is an "*inferior*" planet, or nearer to the sun than ourselves, and her distance from us, consequently, variable to the extent of the whole diameter of her orbit, her apparent diameter as viewed at distances between these extremes of 163 millions and 27 millions of miles, is very different at different times. Accordingly, when nearer to us, although then only a crescent (p. 45),* the surface of that crescent, from its great diameter (60″), affords us her utmost brilliance; although when she is least splendid the telescope discovers her whole disk. From this brilliance, when not too near the sun, she may be seen by the naked eye in the day-time (C, on p. 16); but at night, from this very cause, she is the most difficult of all the planets to define. Shroeter confidently asserts the existence of very high mountains in Venus, and gives their measurements; but Sir John Herschel perceives "neither mountains nor shadows."

The plane of the orbit of Venus is inclined 3° 23′ to our ecliptic plane; her ascending node being about 15 ♊, and her descending node, consequently, about 15 ♐. When therefore Venus happens to be in inferior conjunction on or about the 5th June or 6th December, her dark disk is seen to transit the sun's.

D The relative distances from the earth, of the sun and of Venus at the times of her transit, are known, from the ratio between her revolution or year and our own (N, p. 236), to be as 2½ and 1, nearly. Since then Venus's parallax is proportional to her nearness, if appearing to an observer in Europe at such time of transit, to cross the northern portion of the sun's disk, she must appear to cross it still *higher* up (and therefore enter upon it later and leave it earlier) if watched by his antipodes in the south. From two such simultaneous observations, the *difference* of the parallaxes of Venus and the Sun (and therefore the Sun's parallax), is exactly determined; and hence the occurrence of Venus's transit is extremely important to astronomers.

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* When it was objected to Copernicus, (100 years before the invention of the telescope,) that were his theory true, Venus should exhibit phases like the moon; he replied by maintaining, that such would be the case if the time should ever come when men might see her shape!

The next two transits of Venus will happen on the 8th Dec. 1874, and on the 6th Dec. 1882. The last two transits were on the 6th June 1761, and on the 6th June 1769. For observations on the latter occasion, expeditions to the North and South were fitted out by various European governments; Captain Cook being sent out for this purpose to Otaheite, by our own.

[F] Venus is west of the sun for about 290 days, and when thus preceding him in the apparent daily revolution of the heavens, is called a morning star. She is afterward east of the sun for about the same length of time, and thus following to set after him in the west, is called an evening star. Her time of whole revolution around the sun does not equal one of these periods: *Her continuance thus to the east or west of the sun, being due to our partially keeping pace with her in angular motion around him.*

	MILES.		
Venus's Diameter	7,702	Her mean angular diameter as seen from the earth	35″
Her mean distance from the Sun	68,000,000		

Inclination of her orbit to our ecliptic,	3° 23′
Inclination of her axis to the plane of her orbit,	unknown.

	DAYS.	HRS.	MIN.	SEC.
Periodic time, or length of Year	224	16		
Rotation on axis, or length of Day (according to Shroeter)		23	20	54

MARS.

G Of the superior planets, Mars is the nearest to our earth. As his path is only 47 millions of miles distant from ours, when in opposition to the sun he is nearly five times as near to us as when on the *other* side of that luminary; and his disk, accordingly; varies as much in its dimensions, being at one time as much as 18″, and at another only 4″ in its diameter.

Although thus exterior in his path he is frequently *gibbous*, presenting to us a portion of his darkened hemisphere: this is owing to the relative dimensions of our orbit, which are such as occasionally to render our position in his sky considerably removed from that which the sun is occupying; and thus, like Venus to ourselves, we are occasionally presented to a portion of his surface from which his morning or evening sun is absent.*

H The ruddy disk of Mars is not any easy telescopic object; but Herschel discerns "with perfect distinctness, the outlines of what may be called continents and seas," the "general soil" presenting an appearance "like what the red sandstone districts on the earth may possibly offer to the inhabitants of Mars, only more decided;" the seas appearing greenish, and brilliant white spots at his poles, more or less great and vivid, according as, from the inclination of his axis as he revolves in his orbit, they may have been long exposed to the sunbeams, or are "just emerging from the long night of their polar winter." The same astronomer considers, that the reasons assigned for the probability of the existence of a very extensive atmosphere on Mars, are inconclusive, and that he may be nearly destitute of an atmosphere and clouds.

	MILES.
Mars's Diameter	4,398
His mean distance from the Sun . .	142,000,000
Inclination of his orbit to our ecliptic . .	1° 51′
Inclination of his axis to the plane of his orbit	30° 18′

	DAYS.	HRS.	MIN.	SEC.
Periodic time, or length of year . .	687			
Rotation on axis, or length of day .		24	39	21

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* The pupil will understand that as beheld from Venus the earth must frequently be gibbous, *i. e.*, that portion of *our* disk from which *she* is conspicuous to us must itself be dark, because the sun is absent from it.

MERCURY.

Mercury, the nearest planet to the Sun, is also of comparatively small dimensions. His phases are, of course, similar to those presented by Venus; but since, from the contracted dimensions of his orbit and its distance from us, his greatest elongation is only 29°, his brilliant disk cannot be seen, even when thus most favorably situated, for a longer time than about two hours before sun-rise or after sunset.

	MILES.		
Mercury's diameter	3,123	His mean angular diameter as seen from the Earth..........	8″
His mean distance from the Sun	36,000,000		

Inclination of his orbit to the Ecliptic............	7°
Inclination of his axis to the plane of his orbit.....	Unknown.
Periodic time, or length of year..................	88 days.
Rotation on axis, or length of day................	Unknown.

ASTEROIDS,

OR, "ULTRA-ZODIACAL PLANETS."

K A curious relationship exists among the numbers which represent the distances of the orbits of the several planets from the Sun: the interval between the orbits of Venus and the Earth being about half only of that interval which exists next *beyond* it between those of the Earth and Mars, but about double of that which exists next *within* it, between the orbits of Venus and Mercury.

Until the year 1801, this law of relationship of distance, (which is sustained on each side of Saturn's orbit, in the intervals of Jupiter and of Uranus,) appeared to be infringed in the greater interval between the orbits of Mars and Jupiter. Bode, the celebrated German astronomer who detected this law, had even conjectured that a planet might be found circling between Mars and Jupiter.

On the 1st day of the present century,	CERES	was discovered by	Piazzi of Palermo.
In 1802,	PALLAS	——	Olbers of Bremen.
In 1804,	JUNO	——	Harding of Lienthal.

and M. Olbers, conceiving that these three small bodies were but fragments of one exploded mass, surveyed three times a year the whole region of the sky about Virgo and Cetus; in one of which opposite constellations he supposed the original mass must have been separated; and on the 29th March 1807, discovered VESTA.

The four minute bodies thus discovered, and conjectured by some to be but the larger fragments of a destroyed world, are moving in orbits, now exactly calculated, which mutually intersect, and that *at a distance from the orbits of Mars and Jupiter "tolerably well corresponding with the law in question."*

The largest and brightest of these Asteroids appears only like a star of the sixth magnitude when viewed together with such a star in the telescopes of our national observatory; and such a star has sometimes even been confounded with it, and observed in its stead.

	DIAMETERS.	MEAN DISTANCE FROM ⊙.	INCLN. OF ORBIT TO ECLIPTIC.
Ceres........	1,024 Miles.	263,000,000	10° 37′
Pallas.........	2,099	265,000,000	34 35!
Juno	1,425	253,000,000	13 4
Vesta........	238	225,000,000	7 8

COMETS.

From the earliest ages the presence of Comets has been productive of peculiar and awful impression on the minds of men. They have been regarded as "blazing stars;" harbingers of Divine vengeance; omens of pestilence and general calamity.

> "A fatal sign to armies on the plain,
> Or trembling sailors on the wat'ry main."

Even considerably after the dawn from the gross darkness of the middle ages, they were regarded as cruel and potent agencies, threatening

> "To herdsmen rot; to ploughmen hapless seasons;
> To sailors storms; to cities civil treasons."

The suddenness of their imposing appearance, as well as their apparent nearness and lawlessness, has caused perplexity and consternation even in less remote times.

It is thought, however, that the Chaldeans, as well as Pythagoras, entertained just ideas of Comets, as lasting planetary bodies conspicuous only in the nearer portions of stated paths.

M Newton shewed that the curve described even by the most excentric of comets in the visible portion of its revolution, is such as the law of gravitation produces. Dr. Halley, Newton's cotemporary, calculated the orbits of what he at first supposed to be twenty-four of these bodies from the observations recorded of them, but made the discovery that the orbit of one comet answered to the several records of the years 1531, 1607, and 1682; and from the near correspondence of the periods between these dates, was led to find the identity of this comet with that which had been noted at the corresponding intervals of 1305, 1380, and 1456, and to predict its return in 1758 or 1759.*

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* Halley died A. D. 1752.

N As the time approached, Clairaut, a celebrated French mathematician, encountered all the impediments to an exact prediction of this comet's return—calculated, that, as their positions were, the disturbing force of Saturn must retard it by 100 days, and that of Jupiter by 618 days—and foretold its passage of perihelion as necessarily to occur within a month of 13th April, 1759! The comet, after its seventy-seven years' curve amongst the *invisibilities*[*] of space, arrived within sixty-five diameters of its primary the Sun, on 13th March in that year!

From 1759, the action of the planet Jupiter in one direction, and of the Earth, Saturn, and Uranus in the other, had considerably deranged the orbit of this comet; but it faithfully appeared, (as many of our pupils will recollect,) with remarkable precision, in that portion of the sky towards which all telescopes were directed to meet it at the predicted time.

P Besides that referred to above, and which still justly bears the name of "Halley," the orbits of two comets, of very short periods, are now known and exactly calculated. The one is that of Encke, which revolves in 3⅓ years; and the other that of Biela, or Gambart, which has a period of 6¾ years. Each visit of these comets was formerly regarded as that of a new one; but they are now identified with their several dates, and punctually return to present themselves to the telescope.

Q It is supposed that there are many thousands[†] of comets. Hundreds were recorded, whilst as yet the most conspicuous only could be viewed; and now scarcely a year elapses without the detection of one of these bodies by the telescope. The pupil who uses the globes will understand, that many hundreds more may have approached and receded in tracks which have been invisible, because lying amongst those constellations which are periodically hidden from our planet by the presence of sunlight.

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[*] To twice the distance of Uranus.

[†] See Herschel's Astronomy, p. 301.

R Comets are thought to be immense volumes of vaporous matter of wonderful tenuity, probably inclosing a hollow space, and reflecting the sun's light as well from their interior as from their exterior surfaces. They are frequently accompanied by a long diverging stream of light, which sometimes precedes and sometimes follows them, but which is generally directed *from* the sun. Several, especially of the smaller comets, are entirely without this appendage. Philosophers are, at present, as ignorant as ever of the precise nature and service of comets; but they are all brightest just after passing the sun, and those that have tails have them most lengthened and developed at that period.*

S Their bulks are enormous, but their masses are comparatively inconsiderable :—

1. The smallest or least brilliant telescopic stars have remained distinctly visible, even when the densest part of a comet has intervened between them and the eye.

2. They are themselves much affected by the disturbing forces of the planets, but are not capable of exciting a perceptible disturbance themselves (S, p. 257). One of them (Lexell's, which in 1770, appeared to be revolving in a period of five years), became "*entangled*" in the midst of Jupiter's satellites without deranging their motions, but was itself thus so thrown out of its own ellipse, as not to make its return. (See also Y, p. 274.)

3. In 1827, a comet passed between us and the sun, but was not visible on its disk, even as a speck of cloudiness, whilst so passing.

4. Of the two small tailless comets of Encke and Gambart, the former crosses the ecliptic sixty times in a century: the latter, which is more than 21 thousand miles in diameter, in 1832 crossed our plane *within* the earth's path and at a point not much in advance of her progress. But their masses are so small, and their texture so "filmy, and all but spiritual," that even if, (as some then feared,) in consequence of any disturbing attraction, the comet had been delayed and the earth had passed through its head, it is supposed that such a collision, although "perhaps not unattended with danger," might have issued only in a small deflection of the earth from her course, and a trifling change in the length of our year.

T They are thought to shine only by reflecting the light of the sun :—

1. The largest and most brilliant cease to be visible when attaining

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* The tails of the Comets of 1680 and 1811, when they had passed their perihelion, were not less than 100 millions of miles in length.

five times the earth's distance from the sun; but their diameters are such as to be measurable even when just so disappearing from dimness: so that they first vanish, not from their extreme distance, but from their loss of sufficient sunlight.

V Their courses are extremely excentric :—

1. That of 1680, in its perihelion, was not distant from the sun one-sixth of the sun's diameter. The length of the orbit of Halley's comet is sixty-fold its breadth.

W The planes of their paths are variously and excessively inclined to our ecliptic :—

1. They appear in parts of the heavens in which no other planetary bodies are seen. It will be recollected that Halley's comet, in 1835, was visible in Ursa Major.

X The constant diminution of the period of Encke's comet, is considered as yielding evidence that an ethereal fluid pervades the regions of space.

1. The resistance of such a medium, although insignificant in its effect when opposed to the momentum (G, p. 207) of the solid planetary bodies, is sufficient to diminish the centrifugal force of such a comet; and thus, by contracting the dimensions of its orbit, to shorten its revolution and accelerate its return. (*See note to page* 257.) Philosophers conceive that this may end in its being drawn down upon the sun; unless, as its lessening form suggests, it should become dissipated.

Y Several comets are retrogade, and some probably move in hyperbolas (pp. 22-3), and thus, after visiting us, are probably enticed away to revolve amidst other systems.

THE FIXED STARS.

The pupil is referred to Definitions 4, 5, and 6, on page 26; and to the arrangement on pp. 54-58, as guides to an acquaintance with the Constellations generally. In tracing the heavens, as visible from any part of Great Britain, or from any place having more north latitude than 50°, he will probably be much assisted also in the use of the familiar "Rhymes on the Constellations" (an attempt at a somewhat ludicrous association of very incongruous materials). *See Appendix.* A classical dictionary may be consulted for the history or mythology of these fanciful conceptions. He may find too, a pleasant means of familiarizing them to his eye, in an easy problem given hereafter towards the end of Section III. The twinkling of stars probably arises from constant changes in the state of the atmosphere: their appearance is much more steady at one time than at another.

z As far as the best and most powerful telescopes have reached into space, the existence of something like the law of gravitation seems to be universally indicated. The closer groupings of some even of those stars which are visible to the unassisted sight, suggests the idea of connexion and relationship; and the number of such groups is greatly multiplied when we seek them even with a very common glass.

If, for instance, on some fine night, we look at the Pleiades* without such assistance, and then direct a pocket telescope to the whiteness in Perseus, we shall allow that a similarity of state is probably existing in both groups: but the six of the Pleiades become a numerous company on our applying the pocket telescope to *them;* and the numerous individuals of the speck in Perseus, start into a crowd of clusters in a moderate astronomical telescope.

If we continue our search with this more advantageous assistance, we shall find that many a speck of whiteness that our little pocket tube revealed before, is really a family of individuals like the Pleiades; whilst, as we move our telescope on its pivot, still more numerous patches of filmy light, then quite invisible, are now exciting a desire for a similar search into their secrecies. If the telescope is good, an application of greater power may probably gratify us with the solution or separation of some of these; but many will remain as mere specks of filmy whiteness, whilst still more and fainter specks, of similar character, are coming into view.

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* It was calculated, long ago, that the probabilities against the fortuitous aggregation of these six stars were as *five hundred thousand to one.*

In Herschel's telescope many of these minutest films are clustered firmaments; but several visible in our pocket tube, or even faintly discernible by the naked eye, are filmy still in his best instruments; growing indeed brighter, but only to become more mysterious! One characteristic may, however, be regarded as prevailing in portions, of many at least, of these unresolvable patches of whiteness, (as well as in several of those that are resolvable into stars,) —the indication of an internal attractive power—a tendency to form into a solid nucleus.

B No fewer than 2,500 of such nebulæ and clusters have their places registered: 500 of them being of very recent discovery, during the stay of Sir John Herschel in the favourable climate of the Cape of Good Hope.

C There is a familiar illustration of the distance of the fixed stars on pages 151-2. Our sun, or any part of its system, cannot be less than two hundred millions of millions of miles from the nearest of them! Such a separation, it is conceived, may be necessary for the prevention of mutual disturbances of the systems circling around such suns!

D Does, then, such an interval exist between any two of the individual stars in the group of the Pleiades, or between two such in the speck of Perseus, or other kindred telescopic groups? Such is the gigantic idea of modern astronomy! Our sun is a *star,*—viewed, telescopically perhaps, from the nearest of these nebulous firmaments, only as an individual amongst the myriads of that similar nebulous cluster which we call the milky-way!—perhaps too, apparently *all but in contact* with its nearest neighbours, Sirius, or Capella, or Arcturus, because separated from them to the extent only of two hundred millions of millions of miles!

F For the milky-way extends *all round,* underneath and above us, in the apparent sphere which we call our sky;

and the telescope proves it to be only an enormous collection of stars too distant to admit of their light being separately visible. The inference is, that "we are situated in an immense stratum of stars, the length and breadth of which is very many times greater than its thickness; so that *when we look through the thin part* we see separate stars in sufficient number, but *when we look along the stratum* we see smaller and smaller stars, more thickly placed than before, and terminating in those which are so distant that their united effect is that of a mere cloud."*—(See def. *Galaxy*, p. 54.)

"It is only when we look towards the MILKY WAY, that these bodies seem to retire indefinitely, and finally to be lost in a diffuse *starriness.* In all other places, the intervals between the luminaries are nearly quite dark, as if we were closer on the edges of our bed of stars, and therefore saw through it into the external and obscure vacancies of space. The opinion is thus forced on us anew, that we are in the midst of a mere *group* or *cluster* of stars; and moreover, that it is a group of peculiar configuration, *narrow, but greatly elongated in the line of the milky way.*—*Nichol's Architecture of the Heavens*, p. 13.

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* Professor De Morgan.

DOUBLE STARS—BINARY SYSTEMS.

C Of the myriads of stars, it was supposed until lately, that the brightest were the nearest; but the very small star marked 61 in the constellation Cygnus, has recently been selected for special observation, as being probably nearer than most of the rest. If this be so, it is evident that, of two stars of very unequal brilliance or magnitude, shining nearly *together*, and thus "optically double" in the apparent concave of the sky, the smaller may be millions of miles, or leagues, nearer to us than the brighter or larger.

Many stars too, which appear as single points of light to the naked eye, are *double* in the telescope; the individuals of such couples being, in some instances, equal in appearance, and in others, of very unequal magnitude.

H It was whilst unsuccessfully endeavouring to detect a variation of mutual distance between such a couple (*i. e.*, a parallactic displacement of the nearer one of two such stars, in consequence of the earth's orbitual motion), that Sir William Herschel was led to the interesting discovery that, in numerous instances, these double stars compose "binary systems;" and that although so enormously distant from us as to be utterly unaffected with an annual parallax, they are gravitating towards each other, and moving in regular orbits around a common centre of gravity.

K "Sun around sun, each perhaps accompanied with its train of planets and their satellites, closely shrouded from our view by the splendour of their respective suns, (4, p. 187,) and crowded into a space bearing hardly a greater proportion to the enormous interval which separates *them*, than the distances of the satellites of our planets from their primaries bear to their distances from the sun itself."—*Herschel's Astronomy*, p. 394.

Unless the planets which may be thus invisibly circling around one of such a couple of suns, "be thus closely nestled under the protecting wing of their immediate superior, the sweep of their other sun in its perihelion passage round their own, might carry them off, or whirl them into orbits utterly incompatible with the conditions necessary for the existence of their inhabitants."—*Ibid.* (See S, on page 257.)

Sir William Herschel recorded the places of 500 double stars. It was the *frequency* of such apparent combinations as he proceeded in his search, that led his mind to the improbability of their being, as before supposed, mere appearances of juxta-position. Since his death, the labours of Sir John Herschel, Sir James South, and Professor Struve, have augmented this number to 6000! of which not less than 30 or 40 are ascertained to be revolving systems; and several have the exact forms of their ellipses of revolution determined, and even the periods in which they complete them computed, from the observations taken of their varying relative positions and mutual distances.

[L] Of the stars familiar to those who are using the Celes-Globe:—

Rigel (β of Orion); Polaris (α of Ursa Major); Vega (α of Lyra) and Cor Caroli, are double, and (with the exception of Vega) not difficult to discern. There is also a beautiful triple star in the right fore-foot of Monoceros; and the minute star ε of Lyra (next N E of Vega), which appears as two when examined with a pocket telescope, presents, in one of considerable power, each one of this couple as itself a double star, equally distant from a fifth probably associated in system with them!

But, of other familiar objects, the periods are ascertained:—

In α of Gemini (Castor), the period of revolution is	253 years.
In γ of Virgo*	629
In γ of Leo	1,200
In ε of Boötes (Mirach)	1,600

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* The individual stars composing this, are nearly equal. About the year 1718, they were distant six or seven seconds (an interval nearly equal to the apparent diameter of Mercury, or half that of Saturn); they are now not more than one second separated, and appear in a moderate telescope as one elongated star: they will of course become separated on the other side after many years. The orbit of π of Serpentarius, is presented quite edgewise towards us; the one star of this system is now projected on the other, so that the largest and best telescopes cannot discern more than one star; but they were viewed separately by Sir William Herschel.

The following, from their shortness of period, have already, since their discovery, accomplished the greater portion of a course:—

In ζ of Ursa Major (Mizar), the period of revolution is 58¼ years.
In ζ of Cancer 55
In 70 of Ophiucus or Serpentarius . . . 80⅓

Whilst the next is even far advanced in its second period;—

In η of Corona Borealis . . . . . 43⅓ years.

VARIABLE STARS.

M Other evidences, not less palpable, of activity and system in the immensely distant regions of space, are noted in the appearances of new stars, as well as in the total disappearance of some, and the variation of brightness, or apparent magnitude, of others.

The star 42 of Virgo, as many before, was first missed on the 9th of May, 1828, by Sir John Herschel.

In 1572 a new bright star suddenly appeared in Cassiopeia, which, without perceptibly deviating from its place, increased in brilliance until it surpassed that of Sirius or Jupiter, being perceptible at noon; and finally disappeared by mere gradual diminution of splendour.

It is conjectured that this star is periodical: that it had been seen about 300 years before, and may, therefore, again appear in 40 or 50 years from the present time.

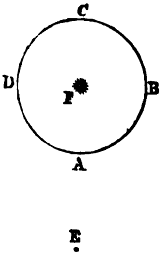
As late as 1670, a new star was discerned in the head of Cygnus, which after becoming invisible made its appearance a second time, and continued two years, till it died away.

Algol **(β of Perseus) varies, with regularity, from the *second* magnitude to the *fourth* in three hours and a half; and in three hours and a half more has regained the splendour of the *second* magnitude to keep it undiminished for two days and fourteen hours.**

It is supposed that this is caused either by the periodical obstruction of some dark planetary body in motion around it; or by the rotation of the star itself, which may thus alternately present a less bright portion of its surface.

Sir John Herschel gives a list of the variations, and periods of variation, of 15 stars.

Separation of the Individual Stars of a Binary System.



Suppose an individual, who fires a gun at A whenever he passes it, be engaged to traverse, with uniform speed, a circular or elliptical path A, B, C, D, and to be required to discharge a musket at the instant of his arrival at C, without slackening his pace. Suppose, now, the exact time occupied in performing this task from A to A again to be 40 minutes and 10 seconds; but that the sound of the distant musket at C be heard by E not after an interval of half that time, or 20 minutes and 5 seconds from his gunfire at A; but after 20 minutes and *ten* seconds, —at which time it is evident that the traveller has been 5 seconds on his way from C towards D.

The listener at E knows, from this circumstance, the distance C A, and consequently, the extent of the path and the rate of the traveller. For, it is evident that the sound of the musket occupied five seconds in its passage from C across to A, and sound is known to travel 1,142 feet per second.

N A method somewhat similar to this, but depending on the fact that light travels with a certain velocity, (R, p. 254,) has been proposed by Mons. Savary, to afford a knowledge of the distance which separates the two stars of a binary system. Let the one star at A be watched throughout its revolution around the other, F. When at A it will be blended with F, and both will appear as one star to an inhabitant of the earth at E (supposed to be at a great distance). It will appear most separated when at B—be again blended with F when it arrives at C—again attain its greatest apparent separation at D, &c.

We will suppose this revolution of apparent blendings and separations to be performed in 62 years. If in the year 1800 the star was at A, in 1831 it was at C; but suppose observation to have ascertained that, although its third blending at A will be in 1862, it *appeared* to be blended by its arrival at C, not in 1831, but in a corresponding month of 1832? it will be evident (as in the other case) that the light which proceeded from the greater distance C, to announce its arrival there, had been just one year in travelling across to A; and since light travels nearly 100 millions of miles in eight minutes, it might hence be inferred by what interval these companion luminaries are separated!

The one half of its orbit will thus appear to have been completed in 32 and the other in 30 years.

"The rule is quite general: observe the apparent times occupied by any revolving star in going through the two *halves* of its orbit; and *half the difference* of these times will be the period in which light passes through the diameter of its orbit."—*Professor Nichol, from Mons. Savary.*

UNKNOWN CELESTIAL BODIES.

The transmission of their light alone, whether direct or reflected, has hitherto been the cause of the discovery of celestial bodies. But it cannot be inferred that others may not exist, even in our own immediate neighbourhood; although it may be safely assumed, from the absence of any *unknown* portion of that disturbing power so wonderfully estimated by modern astronomy (W, p. 259), that if such bodies exist very near us, they must be of inconsiderable mass.

1. Reflecting bodies may be invisible, and thus unknown, because their reflected light is overpowered:—

There *may* be a planet nearer to the sun than Mercury:—there *may* be a satellite of the planet Venus: some astronomers have even thought that, whilst observing that planet, they have noticed a minute crescent form,—just so much of such a companion of that planet as could alone be seen under *our* circumstances.

2. Bodies may be invisible from the feebleness of reflected light at their distance:—

In May 1834, Signor Cacciatore caught a glimpse of what he considered a body in planetary motion, beyond the orbit of Uranus. We have seen (K, p. 278) that, in the judgment of our first astronomers, even the individual stars of the telescopic "binary systems" are suns with planets dependent on them for light and motion. If the variableness of such a star as Algol be caused periodically by the partial occultation or eclipse of one or more dark bodies, those bodies must be of immense bulk, although thus invisible except by their intervening.

3. The greatest of self-luminous bodies may be invisible from the vastness of its distance:—

The largest body in the universe *may* be amongst the faintest of those which are visible only as feeble points of light when the greatest and finest object glasses of Herschel, or Struve, or South, have received and focused them.

4. But even the largest of self-luminous bodies might be utterly invisible, not from its distance, but from its density:—

The huge mass of our sun is little compared with its dimensions:—It has been remarked by La Place, the most famous of French astronomers,[*] that "a luminous star *of the same density as the earth*, and whose diameter should be two hundred and fifty times larger than that of the sun, would not, *in consequence of its attraction*, allow any of its rays to arrive at our eyes!"[†]

NEBULOSITY OF STARS.—ZODIACAL LIGHT.

Q Some stars are marked on our celestial globes as exhibiting a hazy or nebulous appearance in the telescope (Pollux, of Gemini, and ε of Orion, are of this description). Our own sun also is conjectured to be such an one; for although the splendour of his disk, at his comparative nearness, is such as to overpower all other light when he is above the horizon, a pyramid of filmy light, extending[‡] from him to a distance beyond the orbit of Venus, may sometimes be seen soon after sunset, in the fine evenings of April and May, or in the morning dawn of the weeks preceding November (the opposite portion of our year). This nebulous pyramid or cone of light, which is more easily perceived in tropical countries, is now supposed to be revolving about the sun in a period somewhat differing from our year; and to be thus seen, like Venus, sometimes in advance of us, or in that portion of the sky towards which we are moving, and sometimes in our rear.

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[*] See Dr. Dick's *Sidereal Heavens*, p. 314.

[†] We presume on the supposition of the materiality of light (S, p. 186).

[‡] In the plane of his equator, and therefore inclined 7¼° to our ecliptic (p. 240).

THE NOVEMBER METEORS.*

R About eighty years ago a remarkable meteoric shower was witnessed at Quito—a still more remarkable phenomenon of this kind is noted as having occurred in the clear night of the 12th of November, 1779, (upwards of sixty years ago)—on the morning of the 12th of November, in 1799 also, near Cape Florida, for several hours there was "a grand and awful display" of meteors, "as numerous as the stars," as if the whole hemisphere had been illuminated by sky-rockets descending towards the earth.

On the morning of the 13th of November, 1831, meteoric showers were observed from the Ohio country and from along the coast of Spain. On the 13th of November, 1832, from one o'clock until after day-light, there was "a bursting of meteors in every direction," at Mocha, on the Red Sea. In the years 1834, 1835, 1836, 1837, the night of the 13th of November has been distinguished by the same display. The remarkable recurrence of such a phenomenon may be considered as a proof that it is not accidental, and the subject is, at present, one of peculiar interest to philosophers and astronomers.

S One thing most remarkable in these periodical displays, (at least in those which have been duly observed,) is, that every individual meteoric stream and star *appeared to emanate from a particular portion of the sky, which did not change its place except with the general westward movement of the heavens.*

1. Hence, the invisible source of these meteoric streams could not have been merely suspended in our atmosphere; since, if it had been, it must, like the atmosphere, have partaken of the *eastward* motion of the earth.
2. Neither could it have been revolving about the earth as a satellite, for in that case also, it could not have so long retained its apparent place.
3. Neither could it have been moving at a rate much less or much

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* The pupil will find a full and very interesting account of these in Dr. Dick's book just referred to, and from which the substance of our detail on this portion of our subject is chiefly gathered.

greater, than the earth's rate of motion; otherwise, during eight hours of observation, the earth moving as she does 540,000 miles in that time, would either have outstripped it, or fallen short of it.

T From positive observation on the parallax of this source of the meteors, its distance was judged to be about 2,238 miles; and hence it is inferred that this remarkable periodic display arises from the attraction of our planet on some of the nebulous matter of a neighbouring *inferior* planetary body, the parts of which are invisible in themselves, but inflammable by contact with our atmosphere, or by the heat derived from its great compression as they rush through it, (1 of B, p. 175,) and thus visible by being consumed whilst traversing it on their way towards us!

1. Some of the attracted and consumed portions of this body must have been of great size, from their magnificent appearance when at a great distance; their diameters, probably, at least exceeding a quarter of a mile.
2. They must, too, have been of little density, since if their density were considerable, from the rapidity of their flight, their momentum (G, p. 207) must have carried them partly unconsumed, to dash with violence upon the earth's surface.

Putting such facts, and others, together, some of our best astronomers have opinions or conjectures somewhat diversified, but agreeing in their general character.

V M. Arago supposes that there are "myriads of bodies, composed probably of nebulous matter similar to the tails of comets, circulating around the sun, in a zone or ring that crosses the earth's orbit at that part in which she is about the 12th of November;" and that some of these are drawn down by the earth's attraction, from a part of space a little in advance of her, and falling towards her, take fire in our atmosphere in consequence of the rapidity of their motion; and thus appear to emanate from a point towards which* the earth's orbitual motion is carrying us at that time.

W Professor Olmsted of New Haven, (United States,) who has paid special attention to this subject for some years, at first considered that the nebulous matter surrounding the sun, and which in some positions appears as the Zodiacal light (p. 283), might have a very excentric revolution around him in a period of 182 days, (about half our year); and hence that the extreme parts of this nebulous body might be attracted into collision with our atmosphere, just when it attained its aphelion, very near us, on the 13th of November. He is still of opinion that these meteors are owing to the same nebulous matter in revolution; but that its period is only a little less than our year.

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* If the pupil will look at the wooden horizon for 21° ♏, (the sun's place on the 13th of November,) he may notice that the opposite sign and degree, in which *we* are when we see the sun thus situated (F, p. 105), is three signs behind *Leo*, the constellation in which the meteoric shower appeared to originate.

Monsieur Biot's opinion also is, that "the meteoric showers are owing to the Zodiacal light coming into periodic contact with the atmosphere of the earth."*

⁂ Some disturbing attraction may occasionally throw this body out of its course; and thus, by retarding or accelerating its approach, cause an omission of this contact, or bring it in the day-time, when the effect may be invisible; or may even so change the elements of its orbit, (S, p. 257,) as to occasion its absence from us for a number of years.

× The several accounts of the meteoric shower, visible especially in North America on the 13th of November, 1833, describe it variously; but all as having been truly magnificent and awful. For the two hours between four and six o'clock at New York, the meteors are described as having been "as numerous as a thousand each minute!" At Philadelphia one was heard to explode "like a distant sky-rocket!" In the state of Mississippi, the largest of these shining bodies appeared "about the size of Jupiter or Venus when brightest." An acute observer describes the appearance of a star at the emanating point, "less at first than the stars of the constellation by which it was surrounded, but increasing until much larger than the stars, then totally disappearing from ten to fifteen minutes, and then appearing again, the meteors shooting forth in greater numbers in the interval. An account from North Carolina describes one of the meteors as "larger than the full moon!" and at New Haven, either the same or a similar body exploded in its fall, leaving a splendid train.

On the same occasion, 13th of November, 1833, a gentleman in South Carolina was awaked by "shrieks of horror and cries for mercy" from the negroes of the adjoining estates, who were terror-stricken at the display of the meteors, and imagined that the world was on fire:—"Upwards of a hundred lay prostrate on the ground, some speechless and some uttering the bitterest cries, but most with their hands raised, imploring God to save the world and them."

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* *Connexion of the Physical Sciences*, p. 428, 4th Ed.

METEORITES.

Y The "shooting stars" common on fine winter nights, or during the prevalence of dry easterly winds in summer time, have very much the appearance of real stars; darting in straight lines obliquely downward, but sometimes horizontally, and leaving no train. Those of warm summer evenings are, some of them, very brilliant, but have curvilinear motions. A third kind, of a bluish white colour, (generally seen in the intervals of showery weather, and often preceding high winds,) after being extinguished in their course, leave it marked, for some seconds, by trains which widen and become dissipated. Various hypotheses have been offered to explain these, some referring them to combustion in consequence of chemical action, and some to electricity.

But meteoric stones, or aerolites, have frequently been found to have descended "from the bosoms of large luminous meteors," in various regions of the globe; and from strict chemical research on stones having so fallen, at various times, in England, Italy, Germany, the East Indies, and other places, it has been ascertained that they are all compounded of the same chemical principles, and nearly in the same proportions! "At whatever period, or in whatever part of the world, they may have fallen, these stones have appeared, as far as they have been examined, *to consist of the same substances, and to have nothing similar to them*, not only among the minerals in the neighbourhood of the places where they were found, but *among all that have hitherto been discovered in our earth*."—Dr. Ure, *Chem. Dict.* p. 618. (The pupil may see some large and very interesting fragments from some of these bodies, at the end of the saloon appropriated to *geological* specimens, in the British Museum.)

Z "Minute bodies may be revolving,* like the new planets,

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* It has even been given as the opinion of some philosophers, that these falling meteoric bodies may be the minuter fragments of that very planet, once revolving as a whole, but now burst into parts, the largest of the parts of which are circling as the Asteroids; and that the smaller fragments are thus occasionally precipitated upon Mars, or Jupiter, or the *Earth*, according as, in wandering through space, those fragments may come within the spheres of the several attractions of these planets.

(see L, p. 270,) which are so small that their masses may be inappreciable, and there may be many still smaller. Nor is this an unwarrantable presumption; many such do come within the sphere of the earth's attraction, are ignited by the velocity with which they pass through the atmosphere, and are precipitated with great violence on the earth. The fall of meteoric stones is much more frequent than is generally believed; hardly a year passes without some instances occurring; and if it be considered that only a small part of the earth is inhabited, it may be presumed that numbers fall into the ocean, or on the uninhabited land, unseen by man. They are sometimes of great magnitude; the volume of several has exceeded that of the planet *Ceres*. * * * One which passed within 25 miles of us, was estimated to weigh about 600,000 tons, and to move with a velocity of about 20 miles per second—a fragment of it alone reached the earth."—*Mrs. Somerville*.

ZZ Others have conjectured that these meteoric bodies have their origin in the volcanoes, which are thought to have been perceived, on the surface of the moon. It is calculated that, if the eruptive force of such a volcano were equal to projecting a body from its crater at the rate of nearly 11,000 feet per second, such a body would, necessarily, be carried beyond the attraction of the moon's mass; and instead of falling back again upon her, would come within the earth's control; and although perhaps retaining, by inertia, the orbitual direction of the moon, (3, p. 212,) and therefore continuing for some time to circle about us as a satellite, might ultimately be disturbed by the attraction of the sun, fall down into our atmosphere, and thus arrive in a fused or heated state, at the earth's surface.

PROBLEMS, ETC.

SECTION III.

RELATING TO THE TRADE WINDS, THE MOON'S NODES, ECLIPSES, THE TIDES, THE PRECESSION OF THE EQUINOXES, ETC.

THE WINDS—TRADE WINDS, ETC.

B The heat of the sun, in producing partial expansion and buoyancy in the atmosphere, is the originating cause of the currents which we call winds.

The velocity and, consequently, the momentum or force of the winds, vary between limits considerably extended.

A gentle pleasant wind varies from	4 miles to 10 miles per hour.
A brisk gale	15 miles to 30 miles ,,
A storm	40 miles to 60 miles ,,
A violent tempest	60 miles to 70 miles ,,
A hurricane (destructive of buildings and gigantic trees)	80 miles to 100 miles ,,

⁂ The force of wind within the limits given above, as estimated by the pressure it exerts against a square foot of surface placed perpendicularly to its course, varies from an ounce to nearly 50 pounds.

C If our globe were to cease rotating, and one spot only were exposed to the vertical sun, the air would be constantly rising from that spot like the smoke from the chimney of a furnace, and the atmosphere from all parts around would be, as constantly, in motion towards that spot, to supply its deficiency.

As the earth is turning round, and there is thus a belt of such heated parts, and a belt of atmosphere ascending from them;—only with less activity than in the case just supposed, because the sun's heat is not, as in that case, concentrated;—towards this heated belt, currents set in from the hemispheres north and south of it, to pour an incessant supply of cooler and heavier air.

D But, as the calm atmosphere of any latitude has the actual motion only of that latitude, no part of any one of these supplying currents has, for some time, so much westward motion as the lower latitudes of the rotating surface over which it has to pass; it therefore *lags* on the surface, and appears to the inhabitants of the latitude it may be crossing, to have lost all its fellow tendency from the west, as they outstrip it and are thus carried against it towards the east.

The very unequal distribution of land on the surface of our globe—the various nature of the land surface itself, as more or less adapted to the reception and communication of heat, (R and S, p. 173,)—and other local circumstances, interfere much, at all seasons, with the regularity and direction of winds, even in the Torrid Zone. In our own country, and those similarly circumstanced in the Temperate Zones, the winds are proverbially inconstant; although from the same cause of differing velocity in the latitudes north and south of us, from which they come,, our N. wind is a N.E. one, and our S. wind a S.W. one; and these winds blow in England 300 days in the year.

F In the expanse of the vast Pacific and the Atlantic, at considerable distances from land, the winds arising from the influence of the vertical sun prevail almost uninterruptedly as the well-known N.E. and S.E. Trade-Winds.

PROBLEM A.

TERRESTRIAL GLOBE.

To find the result of the transference of a portion of the Atmosphere into a higher or lower Latitude.

Admonitory questions.

a What is the meaning of Inertia? D, p. 207.
b What is the meaning of Velocity? F, p. 207.
c If the Earth were to leave off rotating for an instant, would the sea and the atmosphere immediately stop their eastward course? 6 and 7 of page 212.
d Of places in lat. 60 and lat. 41, which have the greater actual velocity (although affected with the same *angular* motion); and in what ratio do their velocities differ? M, on p. 226.
e What effect has a heated body when applied to the lower portions of a fluid? V, and 4 of V, p. 174.
f Is the transparent atmosphere affected with currents by the sunbeams as they pass through it to the earth's surface? Y, p. 175.
g With what motion, as well as vertical motion, is the atmosphere affected whilst ascending from the Earth, at the Equator (or in any latitude,) in consequence of heat? 3, 4, and 5, of p. 212.

RULE.—(When the difference of velocity is required.) Find (by Rule to Prob. XVIII., p. 101,) the velocities per minute of the two places proposed:—the difference between these two velocities will be the excess or deficiency of eastward velocity in the atmosphere, supposed to be suddenly transferred. If the difference be an excess, the wind will be westerly; if it be a deficiency, the wind will be easterly.

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1. If the inhabitants "under the line" are becalmed, at what rate per minute is their atmosphere moving by the earth's rotation on its axis?

2. If the atmosphere at Quito, or the north of Celebes,

were actually moving 15½ geographical miles per minute, what wind would the inhabitants of those places experience?

3. What if, at these places, the atmosphere were moving only 14½ geographical miles per minute?

4. If the inhabitants of Havannah, or other places in its latitude, are becalmed, at what rate are they and their atmosphere moving?

5. If the calm atmosphere of the Equator could suddenly be transferred (without losing its velocity and tendency) to the latitude of Havannah, what wind would they have, and of what strength as explained by its rate per hour? (See p. 289.)

6. What, if the calm atmosphere of Havannah, or its latitude, were transferred to the Equator, would be the wind experienced *there?*

7. What is the characteristic of that current which, to supply the place of the air raised from the Equatorial regions, (as described p. 289,) constantly flows towards them between the latitudes 30° N. and 30° S.? (II. and III. of 16, p. 68.)

⁂ "The advance of the air from the north and south is gradual, and all the while the earth is continually acting on, and by the friction of its surface accelerating its rotatory velocity." * * * "It follows from this, then, that as the winds on both sides approach the Equator, their easterly* tendency must diminish."—*Sir J. Herschel*, p. 130.

8. Give the characteristic of the trade winds, as noticed by a voyager in passing from Europe through the two Zones, each of 30°, throughout which they prevail? (IV. and VI. of 16, pp. 68 and 69).

G The air raised from the belt of the earth's surface passing under the tropical sun, "flows over" and spreads itself northward and southward, retaining, throughout this northward or southward course, much of the superior eastward velocity of the equatorial regions, but constantly losing some of it* by friction against the more tardy strata of air which it is crossing above. It is at length "sucked down," and descends beyond latitude 30°;† and its eastward velocity being still superior, it there outstrips the surface, and shews itself as a westerly wind almost as regular as the easterly winds of the Tropics which its rising caused.

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* Because their easterly origin is apparent only, and owing to their deficiency of rotatory motion.

1. It has been proposed to carry the Nassau balloon to the United States, and to commit the aeronaut, well stored with provisions, to this constant current for his return to the European shores.

2. A vessel bound for Van Dieman's land, after sailing down near America, across the S.E. trades into a latitude south of the Cape of Good Hope, may often find a wind "right aft" for the whole remainder of her voyage eastward.

9. Which (from a consideration of the above) will be the shorter voyage,—from New York to Liverpool, or from Liverpool to New York?

10. Can a vessel, "homeward bound," sail directly eastward from the West India Islands?

11. What course would *you* contrive, in coming to England from Jamaica?

12. Devise the "best course," under circumstances, for a vessel sailing from Europe to Barbadoes?

13. How might a vessel, bound for Van Dieman's Land, proceed, after arriving from Europe into that part of the Atlantic which is between Buenos Ayres and the Cape of Good Hope? (see 2 of p. 293.)

⁂ The pupil will understand that, as on the large scale already described, so in general,—north of the Equator true north winds appear to be north-east winds, and true south winds south-west ones: south of the Equator, on the contrary, but from the same cause, true north winds appear north-west winds, and true south winds south-east ones.

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* The course of the hurricanes of tropical climates, is generally in opposition to the regular trade-wind; and it is probable they arise from portions of this upper current being "prematurely diverted downward;" *i. e.*, whilst yet its eastward motion is very great compared with that of the surface below.

The ashes thrown up to a very great height from the volcano of St. Vincent, in 1812, were carried by this upper current in a direction contrary to the apparent motion of the trade-wind, and passing over Barbadoes, 100 miles distant, like a dense cloud, partly fell on that island; and even fell thickly on the deck of a vessel 500 miles to the east.

† Rather somewhat farther north than this. In the Pacific beyond 40° N. and S. for ten months in the year, the wind blows constantly from the west, and the time of arrival of vessels from the east to America, may be calculated almost as accurately as the time of the arrival of a mail-coach.

13. What would be the consequence, as it regards their velocity and direction, if it were permitted that bodies of air, calm, (*i. e.*, moving at the same rate and in the same direction, with the places in which they are situated,) could be *instantaneously* transferred to us in Greenwich from the latitude of Madrid?—from that of Bergen or the Shetland Isles?—from the Equator?

14. Does "the churlish chiding of the wintry (east) wind," arise from its rushing against us, or from our running against it?

15. A wind prevails *on* the Peak of Teneriffe, the reverse of that blowing on the seas at its base:—what wind is this, and whence has it its origin?

16. What do you conceive to be the origin of the south-west and westerly gales so prevalent in our latitudes?

Influence of Varieties of Surface.

H The nature, as well as the distribution, of the land-surface, has been alluded to as exercising an indirect but important influence upon the character and tendency of the winds. It has also been mentioned, that it is only in the Great Pacific that there is the absence of such interference with the grand scale of those currents which arise from the united effects of the sun's heat and the globe's rotation.

"In the nicely balanced state of the forces" thus producing the great atmospheric currents, "slight irregularities of temperature are capable of causing great disturbances; and expansions and contractions, acting unequally upon the antagonist currents, operate by deranging the adjustment of their several velocities. Hence accumulations (*of velocity*) in some parts, and corresponding deficiencies in others, necessarily arise."*

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* Dr. Prout's *Bridgewater Treatise*, p. 281.

If the small surface of *our* islands were uniform, instead of being, as it is, thoroughly diversified, our winds would, probably, be of a more determined or periodical character. But even the bolder features of the neighbouring continent are comparatively of trifling prominence and extent, and therefore of feeble influence compared with that exercised in other parts of the globe.

K The snowy ridges of mountain chains have considerable power in cooling the currents which are driving over them; precipitating the moisture they bring (2 of G, p. 179,) on one side, and transmitting them in coldness and density along their declivities on the other.

The Andes draw down torrents from the trade-wind as it ascends them on the east; whilst the confined regions along the west of them are generally dry. At Lima, rain is scarcely known. A December journey of four hours in Peru, conducts the traveller up the Andes from summer to winter.

L Vegetation itself exercises an important influence. Forests not only prevent the access of the sun's heat to the ground, and thus hinder the air from being heated by it, but they cool the air by evaporation from the surface of every leaf! The grassy clothing of the earth itself cools the air, "absorbing more caloric than it gives out." Even in the meadows and heaths of England, the absorption of heat* by the grass is sufficient to cause the temperature to sink to the point of congelation during the night, for ten months in the year."†

1. The graminiferous plains of South America, cover an extent *ten times* greater than that of the kingdom of France; and the forests‡

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* From the atmosphere.

† Mrs. Somerville, p. 285.

‡ In Guiana, within 5° of the line, the inhabitants, living amid immense forests, a century ago were obliged to alleviate the severity of the cold by evening fires. "Even the duration of the rainy season has been shortened by the clearing of the country; and the warmth is so increased, that a fire now would be deemed an annoyance. It thunders continually in the woods, rarely in the cultivated parts."—*Dr. Ure.* The climates of European countries are now much less severe than in ancient times, before the removal of forests and the extension of cultivation. Cæsar says that the winter's cold of Gaul prevented the cultivation of the vine. The barbarians who overran the Roman empire, transported their baggage-wagons across the ice of the Rhine and the Danube.

of the Amazons and Oroonoko, occupy an area of more than 260,000 square leagues.

2. On the coast of Brazil, from September till March, there is a constant wind, like the trade wind of the northern belt, from the N.E., instead of that from the S.E., which belongs to its latitude.

M The pupil may easily conceive how important an agency must exist in the sandy deserts of our globe, exposed as they are to the full action of the solar heat.

1. The deserts of Arabia form the principal feature of that large peninsula. Of three deserts in Persia, the length of one is 400 miles, and of another 350 miles; and deserts extend, with the partial interruptions of rivers and mountains, throughout Asia to the northern confines of China.

But the Asiatic deserts are far surpassed by the Sahara of Africa, which, with very few interruptions, contains an area of between two and three thousand miles in length, and seven hundred miles broad.

2. Near the African coast, the winds, in general, tend toward the coast. It is the humidity thus brought from the sea on all sides, that keeps the countries bordering the desert in a state of vegetation. Off the Grain coast, there is a considerable space where "almost continual calms are found, attended with thunder and lightning; and the rains are so frequent and heavy, that the space has acquired the name of "*the Rains.*"—*Riddle's Navigation.*

3. "It is doubtful whether, if it were not for this same desert, (the African,) the crops in England would come to maturity; and whether our fields would not be ice-bound in winter, and parched and barren in summer. The south west winds which blow over us, if not always at the surface of the ground, during the greater part of the year, and which bring us the rains of spring and summer, and warmth generally, are put in motion by the trade-wind on the Atlantic, and there is no question that the African desert has considerable influence upon that wind."—*Professor Moseley.*

MONSOONS.

Periodical winds distinguish the less open seas within the tropics:—whilst the S.E. trade-wind blows in the middle of the Indian Ocean pretty constantly, the Arabian Sea, the Bay of Bengal, the Chinese Sea, and the other confines of the Indian Ocean to the east and west, have land and sea breezes each of six months' duration, arising from the seasonal effect of the sun's heat.

PROBLEM B.

TERRESTRIAL GLOBE.

To find the result of the transfer of a portion of the Atmosphere into a higher or lower latitude.

Admonitory Questions.

a What is the characteristic of the north Trade-wind belt, and whence is this characteristic acquired? (p. 290.)

b What is the characteristic of the south trade-wind belt? (p. 290.)

c Of the Pacific and Atlantic, which has the less interrupted trade-winds, and why?

d How does vegetation generally, and especially extension of forest, affect the state of the air? (p. 295.)

e What do you judge to be the influence of a state of surface the reverse of this, or the state of interior Africa, Arabia, and central Asia?

Rule.—(Where the difference of velocity is required,) Prob. XVIII. p. 101, as before.

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1. How much slower per minute is the northernmost boundary of Thibet carried by the earth's rotation, than the equatorial parts of the earth are?

2. What is the difference between the velocity of Bombay or its latitude, and that of the Island of Zanzibar, (east coast of Africa,) or its latitude?

3. What is the difference of velocity of Canton and Bencoolen?

4. What is the difference of velocity of Bencoolen and Swan River (New Holland)?

5. What is the difference of velocity of Cape Ambro (N. Madagascar) and Delhi?

6. What is the difference of velocity of Sandy Point (New Holland) and Cape Comorin?

⁂ "*Monsoon*" is a Malay word, signifying "a season." Before the invention of the compass, the Indian sailor committed his vessel to the guidance, as well as to the force, of the Monsoon wind, and filled up his year with one voyage outward and one voyage homeward.

7. During which half of the year are Persia, Hindostan, China, and the deserts of interior Asia, under the heating influence of the more direct beams of the sun?

8. If the air over these countries, becoming heated and expanded, ascend, what will be the consequence to the atmosphere of the seas to the south of them; and especially of that in the neighbourhood of the comparatively cold mountainous extent of the south-east African coast?

9. What will be the characteristic of the atmosphere so on its way to supply the Asiatic regions referred to, these Asiatic regions having less velocity?

10. During which half of the year is the influence of the more direct beams of the sun removed from Persia, Hindostan, China, &c.?

11. What, besides northern, will be the characteristic of the atmosphere of these regions of less velocity, if, thus becoming cooler and heavier than that of the southern regions, it flows down to supply them?

12. During which half of the year is the middle of New Holland rendered warmer than the regions north of it?

13. Give the characteristic of that six months' influx of atmosphere from the equatorial parts, which obtains off the western coast of this huge island, where the velocity is less than that of the regions from which the current is coming?

14. What is the characteristic of the current which, from April to September, flows from the cooled regions of New Holland, toward the warmer equatorial regions?

THE MOON,

ASHTAROTH OR ASTARTE, "QUEEN OF HEAVEN," DIANA,
CYNTHIA, VENUS, URANIA, LUNA, HECATE,

N Is the satellite of the earth, and performs her revolution around us at an average distance of 237,360 miles, her elliptic path having an excentricity of 12,985 miles, and an average inclination to our plane of 5° 9′. Her eastward progress is readily perceived if we note her bearing with regard to a neighbouring star, since she passes, each hour, through a portion of our sky equal to her own apparent diameter, whilst partaking with the star in the apparent westward motion of the heavens.

B The *Periodic* month, or time of exact revolution of the moon, as noted by the interval between her leaving a fixed star and returning to it, is 27 days, 7 hours, 43 minutes, $11\frac{6}{10}$ seconds; but the time of her *Synodic* revolution, or the interval between her leaving the sun and returning to him again, and during which she completes a *lunation* by passing through her phases, is considerably longer than this, or 29 days, 12 hours, 44 minutes, $2\frac{8}{10}$ seconds, because of the sun's "place" amongst the stars having meanwhile changed in the same direction.

P The diameter of the moon is a little more than one fourth of that of the earth: hence, from the moon, our globe has an apparent diameter of nearly four times that which she presents to us, and exhibits a disk thirteen times as great.

The moon has a very small atmosphere:—connected with this fact, the constant clearness of her disk is considered as alone proving that no water exists on her surface; since, if there were water there, it must, at least partly, arise in vapour and thus render her partially obscure. It was formerly thought that the level or darker parts of her surface were extensive seas, and these parts still retain the names which thus described them; but their appearance in good telescopes "is incompatible with the supposition of deep water."

Q The mountains and recesses of the moon's surface have been referred to in F on p. 10,—B on p. 15,—and 5 on p. 193. German astronomers have produced a map of her surface, three feet in diameter, which is considered to be "vastly more accurate than any existing map of our own globe." Her mountains, (which occupy by far the larger portion of that hemisphere which is constantly turned towards the earth,) in very numerous instances present the remarkable character of the jagged edges of volcanic craters, with the "*chimneys*," or more recent products of eruption, standing within them. The shadows cast by the peaks and general outlines of these elevations are, in many cases, as well defined as those of the turrets of our buildings in bright sunshine.

R Little as the moon's distance is compared with that of any other heavenly body, she is yet so distant that no change of her surface, such as that produced on the earth's by cultivation or building, can be discernible in the most powerful telescope: a circular area containing a square mile of her surface, being perceptible only as a speck of one second of a degree in diameter. Shroeter estimated the elevation of some of the insulated lunar mountains at about five miles, or nearly the same height as the loftiest of the Himalayan mountains. Her hollows must, some of them, be nearly forty miles across, and four miles deep!

S A small telescope will shew that the moon is globular:— In one of greater power, the foreshortening of the margins of those of her numerous caverns and mountain rings which are on the more distant parts of the hemisphere presented towards us, is very discernible; and, when examined with a very high power, such parts even require a different adjustment of the telescope, like as when we direct it from nearer to more distant objects on the earth.

If the pupil, thus satisfied of her globular form, will notice the moon on the next *seventh* night of her age, when she will be half full; and, whilst viewing her, will take into consideration that she is shining only by reflection of the sunbeams, he may be prepared to allow,—

1. That, as he is viewing only a quarter of her surface thus enlightened, and the sun enlightens half of every globe exposed to his beams, there must be another enlightened quarter-surface around her margin on his right; this right-hand margin or semicircumference being, in fact, the *meridian that is having noon on that occasion;* and the middle point of it the spot exposed to the sun's vertical rays.

2. That the straight-lined left-hand boundary of her half-disk is, in fact, the western edge of her terminator (see cut on p. 75); a curve coinciding with her semicircumference as much as that on our right, but appearing at this time like a straight line, only because it extends over those parts of her surface that are in the same plane with us, as a hoop appears to be a straight line to the boy who is trundling it.

⁂ On the 6th, or previous, night, this terminator was extended over parts of the moon's surface to the west of our earth's centre; and viewed thus obliquely, it appeared curved in towards our right hand, and we called the moon a *crescent.* On the 8th, or next succeeding night, this terminator will be extended over parts of her surface lying to the left or east, and we shall call her *gibbous.*

3. That, since the mutual distance of the earth and moon is very little compared with the distance of either of them from the sun, (8 of E, p. 194,) he may be considered as, at any time, occupying the same position with regard to both of them; and therefore, as shining upon them almost as if they were *together.*

4. That, since there is always a hemisphere of the moon enlightened, and the other side of her (if it could at any time be viewed), would be found to be exhibiting an enlightened portion of disk, just equal to the deficiency of disk which she is presenting to us; so, at any time, our earth's phase to the moon must be that which answers to this deficiency, since the moon's inhabitants (if she have any,) are viewing that side of our planet which corresponds to the moon's hidden or farther side.

5. That if hollows and eminences crowd the brighter parts of the moon's surface, their shadows must be long in proportion to their nearness to the terminator (at present our left-hand straight line,) because there the sun is in the horizon of the inhabitants. (5 on p. 193.) [The brokenness of light perceptible there, even by the naked eye, is occasioned by real unevenness of surface, her mountain-tops catching the sunbeams earlier than the valleys intervening.]

⁂ If we rise very early in the morning, or sit up late, fourteen days after this, to view the moon when "twenty-one days old," or beginning her "last quarter," we shall find her in the midst of stars opposite to those amongst which we before observed her, and we shall see that the parts which were rising into the sun-beams on her seventh night, are then setting out of them, after a day of nearly 330 hours; a point in the middle of the left-hand half-disk (and therefore the

antipodes of the point formerly noticed on the right,) being that which thus, fourteen days afterwards is receiving the vertical sunbeam.

[T] We may make use of those cloudy specks on the moon's disk, which almost every body forms into a countenance, to fix the pupil's attention to the fact, that although her surface is really rotating towards our right, like the sun's as shewn on p. 240, or like the earth's if viewed under similar circumstances; and thus, some portion of this "countenance" is constantly creeping across the left-hand line or terminator into sun-light; yet her "features" do not pass over her disk and disappear like the spots on the sun:—*This arises from the exact correspondence of her time of rotation, to her time of orbitual revolution.*—If the moon were fixed, like the star of a constellation, the spots of her right-hand edge or "limb," would be continually passing behind her; but just so fast as they are moved by her rotation toward our right, she moves toward our left in her orbit, and thus enables us to keep our view of them.

[V] It will be useful to endeavour to infer (or reconcile) the following, after reading what has been stated of the peculiar motions of the moon.

1. Since, in consequence of the correspondence of the time of the moon's orbitual revolution with her time of rotation, we always have the same part of her surface directed to the centre of the earth:—

a Our planet with its phases (4 p. 301) must be constantly vertical to that part of her surface:—It must be stationary as it regards its altitude and bearing, when viewed from *any* point on her surface; but low in the east, west, north, or south, according as that point from which the earth is viewed is distant to the west, east, south, or north of where it is vertical (Prob. vii. p. 80):—It is constantly in the horizon of those who occupy those parts of her surface which are seen by us to be at the edge of her disk; and for ever hidden from her farther side.

2. Since the moon is revolving around us with an angular velocity of 13° per twenty-four hours, whilst our planet thus appears stationary as regards its bearing and altitude in her sky:—

b The stars opposite to those over which she appears to be passing to us, must (when our light and theirs is not overpowered by the presence of the sunbeams) appear to be passing behind us (F, p. 105).

3. Although our atmosphere must, at least, give our planet a belted appearance,* and more or less obscure the outlines of our continents and seas, the mapping of our globe's surface is probably evident enough from the moon to be a means of exactly marking our daily rotation. But, since the moon's revolution about us is in the same direction as our rotation, and she thus partly accompanies our surface eastward:—

c The time of our rotation, as noted by inhabitants of the moon, will not *appear* to be 23h. 56m. 4sec., but nearly 25 hours; just as the sun's rotation, marked by his spots, appears, when viewed from the earth, to take place in 27 days instead of 25 days, because we are moving around him in the same direction (*see* 4 *of p.* 241; *and, also def.* 88).

W It has been stated (*a* p. 302) that in consequence of the correspondence in period of the moon's rotation and orbitual revolution, one-half of her surface has never been viewed by the earth's inhabitants:—This would have been strictly true if her orbit had been circular, and her velocity of revolution, therefore, such as it is on an average: but the only *equable* motion of the moon is that about her own axis; for her path being an ellipse of considerable excentricity, her orbitual motion is accelerated when she is near her *perigee*, and retarded when she is near her *apogee*. Hence, whilst she is equably rotating,—

d We see a little around her right, or west limb, when her orbitual motion is faster, and a little around her left, or east limb, when her motion is slower than her average rate; the average rate alone according with her rate of rotation. This occasional appearance of a few degrees around her east or west limb, is called her "*libration in longitude.*"

[⁂ Her axis, also, not being perpendicular to the plane of her orbit, we alternately see a little *over* her north pole, and a little *under* her south pole; and this is termed her "*libration in latitude.*"]

Hence, too, there are certain parts of the moon besides one hemisphere, to which the earth sometimes appears.

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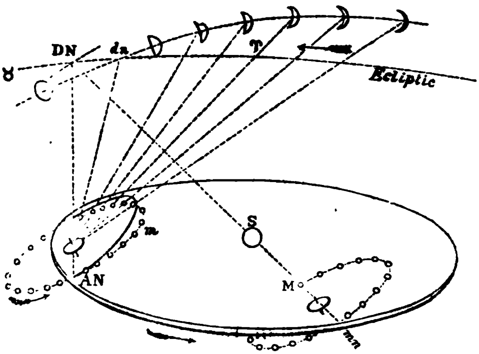
* See "Earth," p. 263.

MOTION OF THE MOON'S NODES, AND OTHER DISTURBANCES OF HER ORBITUAL MOTION.



The pupil will recognize the table as representing the plane of the earth's orbit; and the button of the te-to-tum as shewing the inclined plane of her equator. We have marked out (as before, on page 108), the ecliptic line on parts of the wall in the same plane with the table; but the equinoctial is not inserted, for fear of its being confounded with the plane of the moon's orbit, the inclination of which is necessarily very extravagant.

⁂ We must bear in mind that the moon's path (represented with exaggerated inclination by the little beaded ellipse above and below the table) is *four hundred* times as near to us as the sun (S); and hence, as delineated on the distant wall (or sky), the moon's disk and the sun's disk would be nearly equal (Q, p. 138). The lines joining the te-to-tum (or earth) to the little circles, or beadings, are extended to the wall, and point to those phases, or appearances of the moon in the sky, which result from her several daily positions with respect to the sun and earth.

× We have to refer particularly to the moon's *nodes*—that point in her orbit at which she comes above the ecliptic plane (or table), as A N or *m n*; and that at which, after performing half her course, she descends below that plane, as M, &c.

When at A N, and therefore ascending northward, the moon, as seen from the earth (our te-to-tum), is crossing the ecliptic (on the wall) at a point diametrical to D N, and therefore behind us as we view the diagram. It is evident that, at such an instant, the principal disturbing effect of an attraction exerted from S (the sun), must be that of an acceleration of her progress. But as she proceeds, in consequence of her inertia and the attraction of the nearer earth, to fulfil her course above, the effect of S's attraction is also to drag her downward towards him and the table plane, thus rendering the angle or inclination of the plane of her path less than that of the continuous line which represents what her path would otherwise be; and she proceeds towards *m*, along the dotted line, into the situations marked by the little disks.

Having arrived at *m*, and begun to pass that point, one of the disturbing effects of S is evidently that of retarding her; but this is not all, for his attraction also bends her course into one of greater inclination, and compels her so to *anticipate* her crossing the plane that she goes below it at a point somewhat to the west, or right of that diametrical to A N (at which she came above it); and thus, instead of being seen to cross the ecliptic at D N, she appears at *d n* to form her node. She is similarly accelerated, retarded, and perverted, during the fortnight of her being south of our plane (or below the table); and thus comes up again, not at A N as before, nor even at the point diametrical to *d n*, but at a point opposite to one a little farther still to the right or west of it.

Y To avoid complexity, the earth's motion during the lunation has been disregarded, and that relative position of the sun alone considered which is at right angles to the moon's node. The moon's nodes, as exhibited thus (on our left), are said to be in *quadrature*; that is, she is crossing our plane when a *half-moon*: under these circumstances she is so disturbed as to have her node rapidly regressing, or falling back in an order contrary to that of the signs of the zodiac. But it is evident that, as the earth revolves accompanied by the moon, the sun will be, relatively, in very different positions. It will, for instance, happen (as on the right) that the line of the moon's nodes pass through the sun, or coincide with what is called the line of *syzygy*: whilst this is the case the node is undergoing no change. In other parts of our yearly revolution, as her nodes are variously presented towards the sun, she is variously affected in different portions of her monthly path; but the average result of each month's disturbing attraction of the sun is a retreat of these nodal points of about one degree and a half.

[z] “The actual amount of this retreat of the moon's node is about 3′ 10″ $\frac{64}{100}$ *per diem* * on an average; and in a period of 6793 $\frac{39}{100}$ mean solar days, or about 18 $\frac{6}{10}$ years, the ascending node is carried round in a direction contrary to the moon's motion in its orbit, over a whole circumference of the ecliptic. Of course, in the middle of this period the position of the orbit must have been precisely reversed from what it was in the beginning. Its apparent path, then, will be among totally different stars and constellations at different parts of this period; and this kind of spiral revolution being constantly kept up, it will, at one time or other, cover with its disk every point of the heavens within that limit of latitude or distance from the ecliptic which its inclination permits (p. 299); that is to say, a belt or zone of the heavens of 10° 18′ in breadth, having the ecliptic for its middle line.”—*Sir J. Herschel*, p. 217.

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[a] We must keep in mind that it is the inequality † of the attractions of the earth and sun upon the moon, that is the cause of her perturbations. The moon is differently affected when in conjunction (as at *m*) than when, a fortnight afterward, she is in opposition, or on the other side of the earth; for not only, in the former case, is she nearer to the sun than the earth is by 240,000 miles, and in the latter case, more distant than the earth by the same quantity; but the earth's attraction thus alternately combines with the sun's and opposes it. The moon's monthly orbit itself having an excentricity of rather more than $\frac{1}{20}$, she is, from

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* When the moon's node is given (as it is in the Ephemeris on our page 51, for every sixth day), it must be understood to be the *ascending node* of her *instantaneous ellipse;* that is, such a degree and minute of the ecliptic line as *would be cut by an ellipse which corresponds to the tendency* of that portion of her disturbed path which she is then pursuing.

† See the first lines of p. 257.

this circumstance too, alternately more and less affected by the earth's influence.

C But the excentricity of the earth's orbit also affects the orbit of the moon. When we are nearer to him, or approach our *perihelion*, her orbit is enlarged by the sun's increased attraction, and she moves the slower:—whilst we recede towards our *aphelion*, her orbit contracts, because the earth's control over her is less disputed, and she moves the faster, as a counterbalance to her increased gravity towards us. (D, p. 233, and G, p. 234.)

D The irregularities, or inequalities, arising from such circumstances as the foregoing, are all estimated by astronomers: they are all compensated in short times, and are therefore called *periodical** (W, p. 258). But there is a *secular* inequality of the moon, which is of great chronological interest:—

Eclipses can take place only when the new or full moon is at, or very near to, her node. There would, for instance, be a solar eclipse, that is, the moon's dark body would be seen partly or wholly *upon* the sun, if she were crossing our plane, or nearly crossing it, as at M (see the diagram, p. 304), whilst the earth and the node were in the relative positions represented by the te-to-tum, &c. on the right. Or if, whilst the earth and the moon's node were so circumstanced, the moon were *coming* across our plane (as at *m n*), or nearly so, she would receive *our* shadow, and be herself eclipsed. The times of such occurrences, the pupil is aware, are predicted with remarkable exactness; and it is easy to conceive that laborious calculation, extended backward, might verify the dates of the eclipses which have taken place in past ages. But, in calculating backward, with every advantage derived from the precision of modern discovery and observation, it was ascertained that the precise hour given for the eclipse of earliest authentic record (721 B. C.), as well as the hours of those of ancient intermediate date, did not agree with the hours at which they must have taken place in accordance with the present average motion of our satellite; but that they so differed as to point to the fact, that the moon's mean motion is somewhat quicker now than in ancient time. Astronomers failed to explain the cause of this, until, in 1787, it was accounted for by La Place, from a study of the effect which certain disturbances of Jupiter's orbit, has produced on those of his satellites (see L, on p. 251).

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* The same positions of the moon with regard to the sun, her apogee, and her node, are all repeated, or nearly so, at the end of a period of 223 lunations, or 18 years and 11 days. This is what is meant by the *cycle of the moon's nodes*. It was known to the ancients as the Chaldean *Saros*. The inequalities of the moon's motions which result during these several relative positions must, therefore, also be repeated with the positions from which they so result, however numerous and complex they may be.

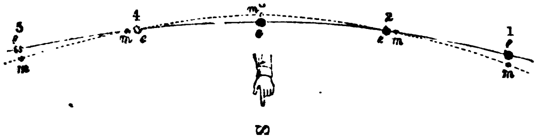
We have learned (T, on p. 257,) that the excentricities of the orbits of the planets are affected by their mutual disturbances; and above (p. 307), that the excentricity of the earth's orbit affects the motion of the moon, by causing her to be taken nearer to the sun at one time of our year, than at another. Now the action of all the rest of the planets upon the earth has thus been, as it were, reflected to the moon; for the earth's excentricity has been diminishing for many ages, and there has been, in consequence, a continual lessening of that portion of the sun's interference with the size of the moon's orbit, which results at and near our *perihelion*.

"The size of the moon's orbit has gradually (but insensibly) diminished; but the moon's place in its orbit has sensibly altered, and the moon's angular motion has appeared to be perpetually quickened. This phenomenon was known to astronomers by the name of the *acceleration of the moon's mean motion*, before it was theoretically explained by La Place. On taking it into account, the oldest and the newest observations are equally well represented by theory."—*Airy's Gravitation*, p. 109.

THE MOON'S REAL PATH.

F The attractions of the sun and earth, alternately united and opposed, render the moon's path about us, comparatively, one of complex irregularity. But such is the sun's mass that, even at his great distance, the moon's gravity towards him is greater than her gravity towards the earth, and keeps her in an orbit every where concave towards him; although, from the proximity of the earth, the attraction of its inferior mass compels her meanwhile to "do service" as a satellite, by producing, alternately, an acceleration and retardation of her motion about the sun.

G It will be interesting to perceive the beauty of that adjustment, by which the Hand that lighted up the sun, and projected the moon as "the lesser light to rule the night," has brought her, in effect, to circle around our earth, by appearing first on one side and then on the other, whilst moving in an orbit about the sun himself, generally speaking, of the same form as our own.



Let the darker, continuous, line represent nearly 1-13th of the earth's orbitual path around the sun; let *m*, the moon, be represented by the smaller of the two dots, and *e*, the earth, be represented by the greater: (the sun being at least two feet distant in the direction given by the little index.) Then, of the five relative positions of the earth and moon, No. 1 will represent their positions at the *new* moon, or the beginning of the lunar month: No. 2, their positions at the quadrature or first quarter: No. 3, at full moon: No. 4, at the second quadrature or third quarter; and No. 5, at the next new moon.

It may be seen, that in pursuing her course along the dotted line from *m* of 1 to *m* of 2, she is moving less rapidly than the earth; but that, in moving during the second week, or from 2 to 3, she goes over a longer space than the earth does during that period. This is also the case in moving from 3 to 4; but she is again retarded in passing from 4 to 5 to be again a new moon, or have that hemisphere which is turned towards us in darkness, or enlightened only by reflection from the earth.

It will be perceived that, whilst thus compelled to accompany the earth by the force of its attraction, the moon is, all the while, yielding obedience to the sun in performing a curve around him; but that the parts of this curve which are gone over by the moon in equal times, are alternately less and greater, as she is alternately under the influence of the *sum* of the attractions of the sun and earth, (as at *m* 3), and the *difference* of their attractions (as at *m* 1, or *m* 5).

PROBLEM C.

CELESTIAL GLOBE.

To find, nearly, the stars over which the moon will pass during several lunations; and to exhibit the effect of various positions of her node upon her altitude.

Read pages 304-306.

Rule (1). Fasten a silken or cotton cord, of little thickness, around the globe; and make it, throughout, coincide with the ecliptic. (It will be found convenient for this purpose, to elevate the North Pole 23½°, and to bring the first point of *Cancer* to the meridian).

2. Find the moon's ascending node, as given below, or in the ephemeris for every sixth day. Place a finger of the left hand upon the cord, exactly at the node's place; and push northward, with a finger of the right hand, that portion of the cord which is exactly three signs, or 90°, in advance of the node, until it is 5¼° to the north* of the ecliptic.

3. At six signs,† or 180°, from the ascending node, is the place of the descending node:—let the finger be placed upon this, so as to secure the cord at this point also, whilst at the 90th degree beyond, it is, in like manner, pushed 5¼° to the south.

4. The position of the cord now marks out the moon's path for the current month; and, since the places of the nodes for any two consecutive months differ only about 1½°, the moon's path for the last month and the succeeding one, as well as that for the present month, is thus nearly represented.

5. The pole being elevated for the latitude given, the points of greatest north and south declination of the cord

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* The degrees of celestial latitude in the Zodiac are, generally, all marked out on the Celestial Globe.

† If the ascending node be brought to one side of the horizon, the descending node will be found cut by the other side, whatever be the elevation of the pole, since there is always an exact half of the ecliptic above the horizon.

when brought to the meridian, will enable us to find the greatest and least meridian altitudes possible, for the month, by counting upward from the south point of the horizon.

Example 1. What stars will lie in, or very near to, the moon's path when her ascending node (☊) is 20 ♓; and what are the greatest and least meridian altitudes she can possibly have during such a lunation in latitude 51½ North?

Here, having placed the cord so as, throughout, to coincide with the ecliptic, I arrange it as directed, by securing it at 20 ♓ and 20 ♍, whilst it is made to range to the 5th degree north of 20 ♊, and the 5th degree south of 20 ♐: and thus placed, it shews that the moon's path (as seen from the earth's centre) will be over δ[*] of Capricornus, δ[*] of Pisces, the Pleiades and β in the Bull's horn, south of Pollux, (β of Gemini,) just north of Regulus, (α of Leo,) just south of Spica, (α of Virgo,) and Antares, (α of Scorpio,) &c. By bringing the cord where its north and south declinations are greatest to the brazen meridian, and elevating the North Pole 51½°, I find that it reaches an elevation above the south point of the horizon of 66½ in one case, and of only about 9½° in the other.

2. The moon's ascending node was 1° ♋:—How did her path then lie with respect to Pollux—Presepe (in Cancer), Regulus, Spica, Antares, α and β of Capricornus, α and β of Aries, the Pleiades, and Aldebaran (Hyades)?

Answer, 5° S. of Pollux, 6° N. of Spica, &c., &c.

3. About nine years and a half after the time of the position of the moon's node last given, her ascending node is 1° ♑:—How does her path now lie with respect to the above-mentioned stars?

4. ☽'s ☊ 1° ♉:—Note the distance of her geocentric path during that lunation, from the Pleiades—β of Taurus (Bull's horn), Pollux, the Presepe (Cancer), Regulus, Spica, γ of Libra, Antares, α and β of Capricornus?

5. ☽'s ☊, 27 ♑
6. ☽'s ☊, 3 ♎

Note, in each of these two cases, the moon's positions with regard to the following stars, and her greatest and least meridian altitudes for those two months, in latitude 51° N.:—Mesartim, γ of Aries, the Pleiades, the Presepe, Regulus, Spica, Antares, β of Capricornus.

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[*] See question 11, p. 162.

7. What are the greatest and least altitudes of the moon possible at her southing in lat. 51½ N., if her ascending node be 1° ♈ :—is not the position of her node given in question 6, nearly the least favourable for her altitude, and which position is least of all so?

8. Refer to the fifth column at the head of page 51: and find by the globe, from the place of the moon's ascending node for the 1st of June, given there, what stars she occulted or made a very near approach to during that month, as well as during the May and July of that year?

9. ☽'s ☊, 17° ♏ :—Where exactly, did the moon's geocentric path lie :—note it particularly with reference to β of Scorpio, Antares, α and β (head of Capricornus), ε of Taurus, and Spica (α of Virgo); and find the greatest and least meridian altitudes possible, under these circumstances, in the latitude of Petersburgh?

PROBLEM D.

CELESTIAL GLOBE.

To find the time of the moon's "transit" or coming to the meridian, her longitude at noon being given.

Rule 1. If the moon be past "full," find her longitude for the noon of the preceding day;—if she be not yet full, find her longitude for the present (given) day.

2. Place the extreme corner of a very small patch of moistened paper, (or a small dot of ink,) on the ecliptic in the longitude thus found.

3. Bring the sun's place to the brazen meridian, and set the hour circle to 12. Turn the globe westward until the mark of the moon's longitude for the last noon come to the meridian, and count the time elapsed:—this would shew the time of her southing, if she had been fixed since the last noon.

4. Now shift (eastward) the mark of her longitude one quarter of a degree for every half-hour elapsed; and this

latter longitude being brought to the meridian, the hour-circle will shew the time of her southing nearly.[*]

Ex. 1. At what time did the moon come to the meridian on the 25th of June, 1840, full moon having happened on the 15th of that month?

Here, since the moon is past full, and indeed in her last quarter, I find her longitude for the 24th or preceding day, and place a mark upon it:—Then, bringing the sun's place for the 25th of June to the brazen meridian, setting the hour-circle to 12, and giving the globe its westward motion until the patch coincides with the meridian, I find that nineteen hours are passed over by the hour-circle.—I therefore remove the patch eastward on the ecliptic, a quarter of a degree for each of these thirty-eight half-hours, or 9½°, and find that the moon's longitude thus becoming 2° ♉, she passes the meridian at nineteen hours and thirty-eight minutes from the last noon, or at seven hours thirty-eight minutes A.M. of June 25. (See "☽'s south." on p. 48.)

⁂ By referring to our page 48, I find that the exact time of the moon's southing was nine minutes later than this, or seven hours forty-seven minutes: this was owing to the quick motion of the moon in her orbit at that time (she being then near her perigee, as may be seen by her great horizontal parallax, in the last column on that page). If, instead of the above allowance of a quarter-degree for every half-hour, we had found the difference between her two longitudes, for the noons of the 24th and 25th, (viz., 14° 15′,) and had multiplied this difference by 19, and divided by 24, that is, had taken nineteen twenty-fourth parts of this, her rate of motion at that time, we should have found that she had shifted eastward not 9½°, but 11¼°, during the nineteen hours; and this would have made our result coincide with the almanac time within two minutes. When she comes to the meridian only a few hours after noon, or when we learn from her parallax that she is not near her perigee, the allowance proposed in the rule will give an answer sufficiently correct.

Ex. 2. The moon was full on the 15th of June, 1840;

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[*] This may suffice for illustration, since the average rate at which the moon outstrips the sun in longitude is 12° 11′ per twenty-four hours:—but for greater exactness, subtract the longitude of the moon for the preceding day from her longitude for the day given, and take so many twenty-fourths of this difference as are denoted by the number of hours, *i. e.*, multiply this difference by the hours elapsed, and divide by 24; and it will shew the advance she has made eastward of her place at noon, and the longitude to be brought to the meridian. The change in the moon's *latitude* made during the hours from the last noon, will not materially affect the result sought for, and may be disregarded.

(see p. 48;) at what time did she come to the meridian of Greenwich on the 10th of June; her longitude for the several noons of that month being given on page 51?

Here we may safely use the allowance proposed in the rule; since we can tell by her parallax (on p. 48), that she was not near her perigee, and therefore not moving very fast at that time.

Ex. 3. The moon was full on the 5th of May, 1841:— at what time did she "south" at Greenwich on the 14th of that month, her longitude for the noon of. the 13th day being 20° ♒ 13'?

Ex. 4. The moon's longitude on 13th Aug, 1841, was . . . 2° ♋ 55'
and on 14th August . . 17° ♋ 42'
} hor. paral. 60¼'

She was full on the 2nd day of that month:—at what time did she transit the meridian of Greenwich on the 14th of August?

Ex. 5. ☾'s long. Oct. 19, 1841, 24° ♐ 20'
Oct. 20 6° ♑ 29'
} hor. par. 55¼'

She was full on the 30th day:—at what time did she pass the meridian on the 20th day?

Ex. 6. ☾'s long. Sept. 10, 1841, 12° ♋ 35'
Sept. 11, 27° ♋ 2'
} hor. par. 60'

She was full on the 1st day:—at what time will she pass the meridian on the 11th day?

Ex. 7. The moon was full on the 28th of November, 1841:—at what hour did she "south" at Greenwich on the 5th of December?

her longitude on the 4th being 29° ♌ 3'
on the 5th 13° ♍ 6'
} hor par. 58¾'

PROBLEM E.

TERRESTRIAL GLOBE.

From the time of the moon's southing on a certain day, and her declination for our noon of that day, to find where she will be vertical at that noon, nearly.

Admonitory Questions.

a If the moon and *Spica* (of Virgo) be together "southing," (or coming to our Greenwich meridian,) at 5 P.M.; in what east longitude was the star southing, just *two hours* before, and in what longitude was the moon then southing, as she must then have been situate about 1° less east than that star?

b I observe the moon on my meridian at Greenwich at the same time with Antares, and just south of that star. The time is 5 A.M.:—in what west longitude will Antares be southing in three hours more; and in what longitude will the moon then be southing; since, in that time, she will have removed about 1½° eastward of that star?

RULE.—If the southing be in the afternoon, turn the time elapsed from noon into degrees, and then subtract one quarter of a degree for every half-hour:* this will give the *east* longitude in which the moon is vertical at noon of that day.

If the southing be in the forenoon, subtract the given time from twelve hours; and the degrees answering to the difference of time, diminished by one quarter of a degree for every half-hour,* will shew the *west* longitude in which the moon is vertical at noon of that day. With the latitude answering to the declination given, and the longitude thus found, the place may be ascertained at which she was vertical (by Prob. XIV. Sect. 1.)

Ex. 1. The moon's declination at noon was 15 south, and she was southing at Greenwich at half-past three, P.M.:—where had she been vertical at noon?

Here 3½ hours answering to 52½° of longitude, the moon must have been situated that number of degrees to the east of our meridian, at the time of noon, if she had been fixed, like a star; but as her orbitual motion has been taking her eastward during those 3½ hours, about ⅞° or 1¾°, she must have been *less eastward* by that quantity at noon, and consequently vertical in 50¾° east longitude, which, in latitude 15° south, answers to *Cape East, Madagascar.*

Ex. 2. The moon, on a certain day, is culminating or southing at Blackheath, or London, at half-past six A.M.; her declination at noon will be 18 north:—where will she then be vertical?

Ex. 3. ☽'s declination for noon 22° 40′:—she was half full, or just completing her first quarter, and passed my meridian at Blackheath at 6 P.M.; where must she have been vertical at our noon if she had been fixed, *i. e.*, without orbitual motion; and where, from a consideration of her orbitual motion, was she then vertical?

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* Because the average rate of the moon's eastward motion amongst the stars, is about half a degree per hour.

If she had been fixed like a star, she must have been vertical in N. lat. 22° 40′, and E. long. 90°; or — ° east of the zenith of ——; but as, since our noon she had gone about 3° eastward, she evidently had been vertical in 3° less east than 90°, or — ° west of the zenith of that place.

Ex. 4. The moon is southing at London, or Greenwich, or Havre, at 12 minutes past 1 A.M.; where will her diminishing disk be shedding its lustre from the zenith, at the instant when the sun is on our meridian on this day: the moon's declination, as given for that instant in the Ephemeris, being 28° north?

Ex. 5. Fourteen days afterward, the moon, being about two days old, was southing 10 minutes past 2 P.M.; her declination at noon had been 28 south:—where had her narrow crescent been discernible in the zenith at that instant?

Ex. 6. On the 18th of May, in a certain year, the moon was eclipsed at 9 P.M. at London: her declination was 23° south (and she was over the heads of the people in the southern parts of Madagascar when thus eclipsed). She came to my meridian at Greenwich, at 15 minutes past 12, or midnight:—where will she be vertical next noon; her declination having, by that time, been changed from 23° to 20¾° south?

⁂ In the foregoing Rule, the allowance made for the moon's eastward motion, of a quarter of a degree for every half-hour, produces only an approximation to the truth; the moon's rate of motion varying with the time of year (p. 307), and with her distance from the earth (p. 303), from a little less than 12° to a little more than 15° per diem. When greater exactness is demanded, we may make use of the Rule of Three to compare the rate at which she is moving per 24 hours, with her quantity of motion for the time required. Thus, if from page 51, we wanted to find how much the moon moved in seven hours on the 2nd of June, 1840, we take her longitude of the 2nd of June, from her longitude of the third of June, and finding thus, her motion for those 24 hours to be 14° 41′, we say

As 24 : 7 : : 14° 41′

and we get 4° 17′ for 7 hours' motion.

In like manner, if the quantity of her motion for 7 hours of the 13th of June, 1840, were required, we find the difference of her longitude for the noons of the 13th and 14th, to be only 11° 53 and

As 24 : 7 :: 11° 53′ : 3° 28′ for the 7 hours of that day.

EFFECT OF VARIOUS POSITIONS OF THE MOON'S PATH UPON HER RISING, ETC.

H Like that of every other heavenly body, the moon's stay above the horizon of any place depends upon the relation which her declination bears to its latitude.

We have learned (see quest. 6, 8, 12, p. 163) that *at* the North Pole, or in a *Parallel Sphere*, her continuance, like that of the sun, or of the rest of the planets, is for half her time at once, because an exact half of her course is north of the equinoctial, which *there* coincides with the horizon.

But the period of the moon's continuance above the horizon of all other places in the regions about the Pole, will be lengthened or shortened by the position of her node; for, as we have just seen, this affects the *extent* of her declination; and she cannot continue twenty-four hours without setting if her declination is less than the co-latitude. *(See note preceding the Rule on p.* 136.*)* When the moon's ascending node is in Aries, her declination (as we have seen from 7 of Prob. C) will become as much as 28¾°, and she may then continue more than the twenty-four hours even in as low a latitude as 61¼°*: whereas, if her ascending node be, on the contrary, in Libra, her declination cannot become more than 18¼°, and then many places even in the Frigid Zone will be without her continuous light; for this declination answers to the co-latitude of 71¾°, and it will be recollected that the polar circle is the parallel of 66½°.

K There are peculiarities in the moon's rising in our lower latitudes, which are occasioned by her rapid change of declination, and these are increased or diminished by the position of her node: but the pupil who has gone over Problem C, will be in no danger of being misled, if, for the sake of illustration, the ecliptic itself be taken as representing the *average* position of the moon's orbitual path.

At the equator, or in a *Right Sphere*, every degree of the eastward motion of the moon amongst the stars produces its full effect of delaying the time of her next rising; for *there* the ecliptic (her average path) has but little inclination towards the horizon: she rises *there*, as she culminates every where, about fifty minutes later each succeeding day (i. e. with an average increase of about 13° of *Right Ascension*). But to any place of considerable latitude, those signs of the ecliptic which are called the Spring signs of the hemisphere, rise with great obliquity, whilst the opposite, or autumnal ones, have, at their rising, more nearly the position which they have in the Right Sphere. The consequence is that, although in one part of the month the daily difference of the times of the moon's rising is considerable, in the other part of the month this difference is far less: for *the daily delay of her rising which would result from her eastward motion, becomes, in a great measure, counteracted, when her course is lying through the Spring signs, by the hastening effect of her increasing declination.* In a high latitude, under certain circumstances, she may (as seen in quest. 11. p. 162) rise for several nights even with the *same* degree of the equinoctial; and, if we elevate the pole to the latitude of the polar circle, we shall find that there, the whole of the six signs that tend towards the elevated pole rise at the same instant.

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* Little higher than the latitude of Petersburgh.

THE HARVEST MOON.

L The moon at full, that is, in opposition to the sun and therefore rising at his setting, can, of course, be in the Spring signs of our hemisphere only when the sun is situated in the Autumn ones, or during our harvest months, and then the hastening of her times of rising, just referred to, which in other months is unobserved because it takes place either in the daylight or during our time of rest, becomes conspicuous. Night after night, for several risings before and after her opposition or time of being full, she is ready with the aid of her light, to enable the husbandman to avail himself of favorable weather for gathering in the harvest; and this especially in the precarious climate of a high latitude, like our own.

M As this phenomenon of the Harvest Moon is produced by her increasing declination, her diurnal arc is increased (Prob. VI. Sect. 1):—and this increase (as may be observed by looking for her in the succeeding forenoons) is made up by the delay of her setting:—for the signs in which, as we have seen, she is then situated, and which have the least difference of *oblique ascension*, are those which have the greatest difference in their *oblique descensions*; and thus, on these occasions, after having hastened to supply us in the evening, she seems, as it were, to loiter, and let her lamp dwindle away in the next day's sky.

PROBLEM F.

CELESTIAL GLOBE.

Given, the moon full on the 23rd September, to find the times of her rising for several preceding and following evenings.

First, taking the Ecliptic as representing the average position of her path.

RULE.—Stick very small patches of moistened paper upon the first point of Aries, and at three intervals of 13° each on the parts of the Ecliptic immediately preceding and following (viz. at 21° ♒—4° and 17° of ♓—14° and 27° of ♈ and 10° ♉). Elevate the North Pole to the given latitude; bring 1° ♈ to the east of the horizon, and set the index to 6.* Then, each of the other patches being brought to the horizon, the time of the moon's rising on the preceding and following days will be shewn (very nearly) by the hour circle; or † the differences of the moon's oblique ascensions on these days may be noted and turned into time.

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* Because the sun is in 1° ♎, setting in the west, and this is the hour of his setting on this day.

† The pupil will find this latter method, of marking the oblique ascension, the more exact and satisfactory.

Secondly, The effect of the position of her node being taken into consideration.

Arrange a white cord or thread to the given node (as in Prob. C), and mark it with dots, from a soft pencil, at intervals of 13°, measured off by the quadrant of altitude from 1° ♈.—Then the index of the hour circle, or the differences of oblique ascension of these several marks when brought to the horizon, will point out the increased or lessened advantage resulting from the position of the moon's orbit.

Ex. 1. Required, the times of the moon's rising in lat. 51½° N. on the 20th, 21st, 22nd, and on the 24th, 25th, and 26th days of September, in a certain year in which she was full * exactly at sunset of the 23rd of that month, and consequently rose at six o'clock:—the longitude of her node being supposed to be such as to cause her path to have an average inclination to our horizon.

Ex. 2. Required the times of the moon's rising, on those days, in latitude 56° of the same longitude.

Ex. 3. Required the times of her setting in latitude 56° on these occasions.

Ex. 4. Find what would have been the several times of the moon's rising on these occasions in latitude 51½° N., if her ☊ had been 1° ♈.

Ex. 5. And what would then have been the times of her rising if our latitude had been 56° instead of 51½°?

Ex. 6. What, if the latitude had been 60° N.?

Ex. 7. Find what would have been the several times of the moon's rising, on the evenings mentioned, in the latitudes of 51½° and 60° N., if her ☊ had been 1° ♎.

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* We have taken the precise time of sunset of the 23rd September; but the illustration is a fair one; for the pupil will readily allow that the circumstances would not have been very different if the moon, instead of being full at 1° ♈, had been full a week before, or a week after; that is, when the sun's place was 23° ♍ or 8 ♎, and her longitude must have been 23° ♓ or 8° ♈.

PROBLEM G.

TERRESTRIAL GLOBE.

Given, the moon in the zenith of a certain place at the instant of her occultation of a star, &c., to find her appearance with regard to that star from certain other places.

[The parallax of the moon, &c., is explained in pp. 18, 19, and it is there also mentioned that, seen in the zenith, she is in her true or geocentric position (def. 99). Her greatest or horizontal parallax varies (as may be seen by tracing down the column on the right hand of p. 48) from more than 61′ to less than 54′. This is owing to the excentricity of her orbit, and to her being thus alternately nearer to us and more distant from us.

The moon's various parallax for the various altitudes at which she may be under observation, is given in books of navigation, &c. We insert an extract below the rule, but give the zenith distance, or complement of her altitude, instead of the altitude itself, as more convenient for the present purpose.]

First, the bearing of the zenith in which the moon was situated being given.

Rule.—Elevate the pole for the latitude in which the moon is vertical, or (which is the same thing) for the declination of the star or of the moon's *geocentric* place. Bring the place where the moon was vertical, to the brazen meridian, and affix the quadrant over it in the zenith:—the nut of the quadrant may thus represent the moon.

Find, now, the distance of the other proposed place, by bringing the graduated edge of the quadrant to it, and counting the intervening degrees; and they will shew the zenith-distance of the star at this place at the proposed instant. Against the number of degrees most nearly according with the zenith-distance, in the table given below, the parallax of the moon will be found:—If the moon's bearing was *north* of the place of observation, her parallactic displacement was northward; if her bearing was *south*, her displacement was southward; if *east*, it was eastward; if *south-east*, it was south-eastward, &c. &c.:—the

parallax being, in every case, a depression toward the horizon.

Zenith Distance.		Near Apogee.		Near Perigee.
20°	☽'s parallax	18′	. .	20′
30°	. „ .	26′	. .	30′
40°	. „ .	34′	. .	36′
50°	. „ .	40′	. .	45′
60°	. „ .	45′	. .	51′
78°	. „ .	48′	. .	55′
80°	. „ .	48′	. .	55′
90°	(i. e. ☽'s hor. par.)	54′	. .	61′

Ex. 1. Suppose the north "limb" of the full moon to be *touching* Antares, as beheld, at a certain instant, very near the zenith at the island of St. Catherina (east coast of South America);—how would she appear with regard to that star from the following places, from which the zenith of St. Catherina has the several bearings annexed to them; the moon being supposed to be near her apogee, and the diameter of her disk being 29′?

From[*] South Shetland,	St. Catherina	bears	N.N.E. (nearly)
[†] Cape Verde .	„	„	S.W. by S.
[‡] London . .	„	„	S.W.
[‡] The Marquesas .	„	„	E.S.E.
California (south point of)		„	S.E. by E.
Cape of Good Hope	„	„	W. by S.

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[*] Here I find that the principal island of South Shetland is distant from St. Catherina 37°; and consequently Antares, when in the zenith of St. Catherina, must have been at that distance from the zenith of South Shetland. By referring to the little table, I find that at 40° zenith distance the moon is displaced about 34′; and as she bore N.N.E. from South Shetland, instead of appearing, as at St. Catherina, to be south of the star, and touching it with her north limb, her whole disk of 29′ was thus, by parallax, made to appear on the other, or N.N.E. side of it; and with her S.S.W. limb, about a sixth of her apparent diameter distant from it.

[†] Here, the zenith of Cape Verde being about 51° distant from that of St. Catherina, and the zenith of St. Catherina bearing S.W. by S. from it, I find that the moon, instead of appearing at Cape Verde to touch Antares at that instant, was cast, by parallax, not less than 40′ (or once and a quarter her apparent width), *below* the star, *to* the S.W. by S. of it.

[‡] It will be observed, that at London and at the Marquesas, the

Secondly, the bearing of the zenith in which the moon was situated being required, as well as its distance.

RULE.—Find the angle of position, or apparent bearing of the place at which the moon and star are vertical, by elevating the pole for each place of observation separately, and attaching the quadrant over it (as in Prob. IX. Sect. 1.), and the several distances of the zenith in which they are vertical may be counted at the same time on the quadrant: then use the table as before.

Ex. 2. Suppose the southern limb of the full moon were seen, at Madras, to come into apparent contact with Regulus, at an instant when that star is in the zenith there,—at which of the following places will the star at that instant appear to be detached from the moon;—at which of them will she be seen with her northern instead of her southern limb near the star;—and at which of them will the star be, at that instant, hidden by the moon's disk:—the moon being near her perigee, and her apparent diameter 32′?

- [*] London
- St. Helena
- Cape of Good Hope
- Botany Bay
- Canton
- Delhi
- Alexandria

Ex. 3. At twelve minutes past one in the morning of 2nd June, 1831, the moon, as seen from Blackheath, occulted the planet Jupiter. These two planets were, at that instant, vertical at Cape East, Madagascar, where (the time

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moon and star were very near the horizon; but that, the one place was leaving their light, and they were consequently setting to it; whilst at the other, or western place, they were near the eastern horizon.

[*] Here, elevating the pole to the latitude of London, screwing the nut of the quadrant in the zenith, and bringing London underneath it, I can find the degrees of distance, as well as the bearing, of the zenith of Madras.

being about half-past four, A. M.) they were both visible:—could there have been this phenomenon *there*, the moon having passed over Jupiter, as seen from Blackheath, at about 6′ distance only from her south limb:—and, if not, how did the moon and Jupiter appear situate with respect to each other in the zenith of Madagascar, the moon being then near her perigee?

Ex. 4. Suppose that on the 2nd April, in a certain year, at the instant of noon at St. Helena, the centres of the sun, moon, and earth were in the same straight line, and the disk of the moon were thus exactly covering the sun's disk, as beheld near the zenith of Cape Palmas (Ivory Coast, Africa); what would be, at that instant, the appearance of this eclipse at St. Helena, at Gibraltar, and at Land's End; the moon being near her perigee, and her disk, therefore, having nearly the same apparent diameter as the sun's at that time of year, or nearly 32′?

Ex. 5. What, at the same instant, was the appearance of this eclipse from St. Antonio (Cape Verd Isles), from which Cape Palmas (and therefore the sun and moon) bore nearly S.E. by E.; from Mecca, from which they bore W. by S.; and from Rio Janeiro, where they were bearing N.E.?

ECLIPSES.

The subject of eclipses has been anticipated on pp. 194, 195, in the illustrations given there of the *umbra* and *penumbra* of the earth or moon. The circumstances which occasion eclipses have been described, also, on our page 307, where the reference is to the diagram illustrative of the moon's node, on page 304. The pupil is, therefore, requested to re-peruse those portions in the following order:—

First, D and its note on page 307;—then note on p. 306;—then D and its notes 2, 4, 8, on pp. 192—4;—and, lastly, F and its notes, with their illustrations, on pp. 194—5.

N If the moon's revolution about the earth were performed in the same plane with the earth's revolution about the sun, it is evident that in each synodical period (B, p. 299) there would be two eclipses, for she would once come between the earth's centre and the sun's, and thus intercept his beams; and once pass through the earth's shadow, and be herself deprived of them.

P If the moon's orbit, although not in the same plane with the earth's, were *parallel* with it (that is, either northward or southward of it equally throughout), whilst less separated from it than the sum of her horizontal parallax and the semidiameter of her own disk and the sun's; then, from what we have attended to in Problem G, the pupil will understand, that each time she was "new," or in conjunction with the sun, she would be seen to *overlap* his disk when viewed from certain parts of our earth's surface. On account of the great width of the earth's conical shadow at the moon's distance, she might, also, under such circumstances, be involved in a portion of it each time of her being full.

Q But, as the moon's orbit is inclined 5¼°, she can "eclipse" or occult a portion of the sun's disk, only when she is "new" either *at* one of her nodes, or so near to it as that her parallax may cast her northward or southward to the solar disk: and when in opposition, or full, unless within certain limits of distance from a node, she will either be above or below the cone of the earth's shadow.

R The moon's parallax, as well as the diameter of her disk, varies with her distance from us; and according, also, to her distance when full, will be the width of that part of the earth's conical shadow which may be lying near to or across her path. But astronomers calculate that if, when *new*, the moon (and consequently the sun) be only 16° 58′ from either of her nodes, some portion of her disk *may* be projected upon the sun's, as viewed from some parts of the earth; or if, when full, she be only 11° 25′ 40″ from either node, she *may* have to pass within a portion of the earth's shadow. These are what are meant by "ecliptic limits."

S The sun, at an average, appears to advance through 29° 6′ during the synodic period, or time of lunation; and therefore *must* be passed, and at least partly occulted, by the moon, *once* during each of the two half-yearly periods at which he is situated within 16° 58′ of one of her nodes; for having arrived within this limit of 16° 58′ on one side of a node, he must, of course, pass through the double of this, or 33° 56′, to get as far on the other side of it; and during the time of his progress through this portion of the ecliptic, the moon must, at least, *once* overtake him. But the full moon, in the fortnight following each of such two half-yearly occurrences, will not necessarily be herself eclipsed; for the lunar ecliptic limits being, (as mentioned above) only 11° 25′ 40″ on each side of the opposite node, or only 22° 51′ 20″ in all, the shadow of the earth, travelling, of course, just as fast as the opposite sun which projects it, is less than a month in moving through that space, and the full moon *may* therefore escape it.

Hence, *the least number of eclipses* will be *two;* and if there be only two, they must both be *solar eclipses.*

[T] But there *might* be as many as *seven* eclipses in the year:—Thus, suppose, at the very commencement of a year, the moon's node were little less than 17° in advance of the sun's place when the new moon overtook him, and consequently occulted a part of his disk,—she must occult him again when next she overtook him, and became new; for he would even yet have proceeded only to about the thirteenth degree beyond her node.

[V] In consequence of the regression of the nodes, the sun would again be found within this limit of distance from the opposite node, when he had advanced in the ecliptic, not 180°, but about 170° only; and this portion of his progress he makes in 173 days. Now six lunations occupy 177 days; and thus the moon, in the case supposed, would meet with the sun, when new her seventh time, under circumstances differing but little from those under which she had met with him when new the first time; and, therefore, not only the seventh, but the eighth new moon would eclipse him. But there would be yet another, or fifth solar eclipse in the year proposed; for as the lunar year (or twelve synodic periods) occupies only 354 days, its 13th new moon would, in consequence of the regression of the node, find the sun again within the ecliptic limits.

It is easy to perceive that, under such circumstances, the first full moon, and the seventh also, must have been involved in the earth's shadow, and that very near the node: for the sun, after the first new moon for instance, would just have had time to get from a little less than 17° to within 2° of the node, and consequently be casting the earth's shadow within 2° of the opposite one, when the moon arrived to receive it. We see, then, that there *might* be seven eclipses within the year, five of them being solar.

W The sun and moon are, during the year, as much below the horizon as they are above it; and, hence, taking the average number of eclipses to be four—two of the sun and two of the moon—the average of visible eclipses will be *one* solar and *one* lunar. We know that, in consequence of parallax, the sun may be appearing clear of the moon's disk from many parts of the earth even whilst entirely eclipsed by her as viewed from another part. A lunar eclipse, however, is visible from half the earth's surface at once; for, when shadowed by the earth, the moon is seen thus from all places to which she is above the horizon.

X The duration of a lunar eclipse depends upon the distance of the sun from the earth at the time, as well as upon the moon's distance; for upon these circumstances depend the dimensions of the earth's shadow where it is crossing the moon's path, and the rate of her passage through it. But the earth's shadow extends three times and a half as far as the average distance of the moon, and its dimensions *there* are, at least, equal to $2\frac{2}{3}$ of her diameters; so that (partially and wholly) she may continue as long as $3\frac{3}{4}$ hours eclipsed by it. For nearly an hour, also, before she enters the umbra, and after she leaves it, the penumbra may be perceived obscuring a part of her disk.

Y The moon is not invisible even whilst totally in the earth's shadow. The atmosphere all around the disk of our planet, as beheld from the moon, refracts some of the light of the hidden sun into our shadow; and a portion of this reaches the moon. It would seem that the light thus refracted is decomposed (V 2, p. 187), and the other parts of it becoming absorbed, the *red* rays principally reach the moon. In the total eclipse of 2nd September, 1830, she appeared of adeep blood-colour when most obscured.

Z The duration of a solar eclipse, even if total, depends upon the distances of the sun and moon from the earth's centre; for upon their relative distances depend the relative sizes of their disks; the moon's disk sometimes being less and sometimes greater than the sun's disk. Her passage across him, too, is performed in a less or in a longer time, according as she is near her apogee or her perigee.

B When the new moon is nearest to us and the sun at his greatest distance beyond her, her shadow, although then the longest possible, does not much outreach the earth's surface: we are so near its apex or termination, that it obscures an area of not more than 180 miles broad, and this, at the utmost, is the whole extent* of a total eclipse at any one instant. But the moon's penumbra (see F, p. 194-5,) is at the same time extending over a circular space of 4,900 miles in breadth; and from all stations within this space, various portions of the sun's disk are occulted.

C When the moon is at more than her average distance from the earth, no *total* eclipse of the sun can take place; for her shadow is shorter than her average distance, and if the centre of her disk be then seen to coincide with that of the sun's, his circumference appears all around her, and we have an *annular* eclipse (lat. *annulus*, a ring).

A solar eclipse cannot continue annular longer than twelve and a half minutes, nor total longer than eight minutes.

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* This darkened area of 180 miles' diameter, if viewed telescopically from the distance of Mars or Venus, would be seen like a round blot traversing the wider or narrower part of the earth's disk, like the shadow of a satellite of Jupiter as it moves across him (see 4 of D, on p. 192).

RECURRENCE OF ECLIPSES.

The remarkable correspondence (note on p. 307) of the time of a complete revolution of the moon's node with 223 of her synodic periods or "lunations," causes a perpetual recurrence of the eclipses which take place during that time.

The following extracts from an extended table of eclipses, calculated by a French astronomer as visible from Europe, Asia, and Northern Africa, will serve to exhibit a few remarkable instances of the return of such eclipses.

1842 ☽ P Jan. 26 ✳ *July* 8 ☽ P July 22	6 A 7 M 11 M	1861	✳ *Jan.* 11 ✳ *July* 8 ☽ P *Dec.* 17 ✳ *Dec.* 31	1880	✳ *Jan.* 11 ☽ T June 22 ☽ T *Dec.* 16 ✳ *Dec.* 31
1843 ☽ P *June* 12 ☽ P *Dec.* 7 ✳ *Dec.* 21	8 M 0⅓ M 5½ M	1862	☽ T *June* 12 ☽ T *Dec.* 6 ✳ *Dec.* 21	1881	✳ May 28 ☽ T *June* 12 ☽ P *Dec.* 5
1844 ☽ T *May* 31 ☽ T *Nov.* 25	11 A 0¼ M	1863	✳ *May* 17 ☽ T *June* 2 ☽ P *Nov.* 25	1882	✳ *May* 17 ✳ Nov. 11
1845 ✳ *May* 6 ☽ T May 21 ☽ P Nov. 14	10½ M 4½ A 1 M	1864	✳ *May* 6	1883	☽ P Apr. 22 ☽ P Oct. 16 ✳ Oct. 31
1846 ✳ Apr. 25 ✳ *Oct.* 20	5½ A 8½ M	1865	☽ P Apr. 11 ☽ P *Oct.* 4 ✳ *Oct.* 19	1884	✳ Mar. 27 ☽ T *Apr.* 10 ☽ T *Oct.* 4 ✳ *Oct.* 19

[D] During eighteen years and eleven days, the time of this revolution of the moon's node, there are about sixty eclipses—twenty-one of the moon and forty-one of the sun—and since the sun, moon, and earth, at each termination of this period, are nearly in the same relative positions, the series of eclipses recommences in nearly the same order.

PROBLEM H.

CELESTIAL GLOBE.

Having the time of new or full moon, to find whether an eclipse be possible.

1. For the time of new moon :—

Rule.—Find the place of the node, and adjust the cord as in Prob. C :—If the sun's place in the ecliptic for the given day be within 17° of either node, there will be a solar eclipse.

Whether places to the north of the sun, or to the south of him, may view this eclipse, will depend upon the situation of the moon as north or south of him.

2. For the time of full moon :—

Find the place of the node, and adjust the cord as in Prob. C :—If the sun's place be within 12° of either node, the moon will be eclipsed at the same distance on the corresponding side of the opposite one.

Ex. 1. There was a new moon on the 25th of March, 1838, at which time the longitude of her ascending node was 14°, (or 14° ♈) :—was the sun then eclipsed; and if eclipsed, could it have been viewed from places in the northern hemisphere?

Here, having adjusted the cord, I find that the sun was within 9° of the moon's ascending node, and consequently was eclipsed. As the longitude of the new moon coincides with the sun's, like him she was west of her ascending node, and had not yet arrived at it; she must therefore have been to the south of the sun, and projected on his disk by parallax only from some southern places.

Ex. 2. There was a full moon on the 9th of April, 1838, at which time her ascending node was 13 ♈ :—did she escape eclipse?

Here, having adjusted the cord, I find that the sun, by this time, had advanced only 6° to the east of the moon's ascending node; the moon, therefore, was eclipsed 6° on the corresponding side of her descending node, or in 19° ♎.

Ex. 3. The moon was full on the 1st of May, 1836; her ascending node was then 20° ♉ 34:—shew her longitude, and state whether she escaped the earth's shadow?

Ex. 4. Fourteen days after this, (or May 15,) did the new moon eclipse the sun; the moon's node having regressed to 19° ♉ 50:—and give reasons for supposing, that if eclipsed, the sun was not visibly eclipsed to certain latitudes?

Ex. 5. Did the new moon of the 8th of November, in the same year, (1836,) eclipse the sun: the moon's ascending node having, by that time, become 10° ♉ 30:—and if eclipsed, from which hemisphere could he not have been seen eclipsed, although above the horizon?

Ex. 6. Was the full moon of the 7th of March, 1841, eclipsed, her node being 16° ♒ 47′?

Ex. 7. Was she eclipsed when full, on the 2d of August, her node having then become 9° ♒ 0?

Ex. 8, Could she have been eclipsed at the next time of being full? Why, or why not? (S, on p. 326.)

Ex. 9. Was the sun eclipsed on either of the two following occasions of his conjunction with the moon, viz.?

Feb. 21	1841	Pl. ☽'s	☊	17° ♒ 30′
Mar. 23	1841		☊	16° ♒ 0′

Ex. 10. Find what eclipses took place under the several circumstances given below:—

In 1839.

New moon 15th of March	☊	25° ♓ 0′
Full moon 30th of March	☊	24° ♓ 10′
New moon 13th of April	☊	23° ♓ 30′
New moon 7th of Sept.	☊	15° ♓ 45′
Full moon 23d of Sept.	☊	15° ♓ 0′

In 1842.

New moon 8th of July	☊	20° ♑ 50′ or 290° 50′
Full moon 22d of July	☊	20° ♑ 18′ or 290° 18′

PROBLEM K.

TERRESTRIAL GLOBE.

A time being given at which the sun is eclipsed where it is passing the zenith, to find where, also, at that time, the eclipse may be visible.

The pupil who has answered the questions given under Prob. G, will be aware that, from the effect of parallax, the moon's disk may be seen upon the sun's from some places whilst he may be quite clear of her as viewed even where he is in the zenith. The path of the moon's *shadow*, (or total eclipse,) like that of the little round blot over the disk of Jupiter, (4, p. 192) can be ascertained only by nice astronomical calculation. In the present instance, the circumstances of the eclipse *where* the sun is vertical are merely *imagined* for the sake of the illustration.

First:—*For the instant of the sun's being totally eclipsed in the zenith of a place:—*

Rule.—Represent the position of the earth's surface with respect to the sun, by rectifying the globe for his declination and the given hour (as in Prob. V. p. 120). Attach the quadrant to the sun's declination, and consequently over the place to which he is vertically eclipsed:—then, note all places within 35°* of this place, as those over which the moon's penumbra is extending; and from which, consequently, various portions of the sun's disk are occulted at that time.

Secondly:—*For the instant at which the sun is very slightly eclipsed in the zenith of a place:—*

Arrange the globe, as before, for the declination and the time; and attach the quadrant to the declination; then, whilst to many places within a short distance only of that to which the sun is vertical the sun is not eclipsed, to others, within as much as 70° in an opposite direction, the moon may be seen variously occulting him.

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* Because the moon's penumbra may be considered to be 70° broad. (See B, on p. 328.)

Ex. 1. Supposing the sun to be totally eclipsed where he was vertical when it was three quarters past three P.M., at Greenwich, on the 15th of March, from which parts of the earth might he appear eclipsed in various proportions at that time?

Here, the eclipse being total very near the zenith of *Panxis*, (mouth of the Tapayos,) on the Amazons, it would be visible, variously, at the instant, to all within 35° of that place; viz., to Buenos Ayres, and all north of Buenos Ayres in Southern America, half of Cuba, the island of Jamaica, St. Domingo, the Virgin and Caribbee islands, &c. &c.

⁂ The inhabitants of the Galapagos, Havannah, and the Bermudas, seeing, at that instant, only a mere contact of the sun's disk by the moon, and each at a different limb; and the Cape Verde islands, at that instant, just escaping a view of the eclipse.

Ex. 2. Supposing the sun to have been totally eclipsed, or very nearly so, in the zeniths of certain places, at the Greenwich times given below, from which parts of the earth may the moon's disk have been seen overlapping the sun in various degrees?

April 25, 5½ P.M.—Dec. 21, 5½ A.M.—July 23, 11¾ A.M. —January 11, 11 P.M.

Ex. 3. On the 24th of February, in a certain year, one digit of the sun's disk was eclipsed in the zenith of a certain place, when it was forty minutes past twelve at Blackheath. Now, supposing it to have been the sun's north "limb" that was so eclipsed at that instant, could an eclipse have been then visible at the Cape of Good Hope; and from what places may it then have been visible to a greater extent than it was in the zenith?

Ex. 4. At sea, lat. 5 south, my Greenwich chronometer shewing six hours forty minutes A.M.; but the sun being in my zenith, with two digits eclipsed on its east limb:—could my friends at the Cape or the Mauritius, have been viewing an eclipse at that instant:—was it visible to those I had lately left at Batavia, or where else was it, probably, visible at that time?

PROBLEM L.

TERRESTRIAL GLOBE.

The time of a Lunar Eclipse being given, to find to what places it may be visible.

Since, when eclipsed, the moon must be in opposition to the sun, or very nearly so, she must be above the horizon of all those who are out of sunlight; hence,

Rule.—1. Having rectified the globe for the sun's declination, and arranged the surface for the given hour, as in the last problem (or by Prob. V. p. 120), we may mark all those places situated along the eastern edge of the terminator, and therefore setting out of sunlight, as having the moon rising eclipsed; and those along the western edge of the terminator, and which consequently have a rising sun, as those to which the moon is setting.

For the convenience of observing the various zenith distances, or altitudes, at which the moon appears eclipsed from the several places to which she is above the horizon:—

2. Now elevate, to the same number of degrees, the contrary pole, or that which is of the same name as the moon's declination; and setting the index to twelve, turn the globe twelve hours, or half a rotation. Then screw the quadrant to the degree of declination in the zenith, as the moon's situation; and its graduated edge, brought to coincide with any proposed place, will mark the altitude at which she is there appearing eclipsed at the given instant.

Ex. 1. On the 26th of January, 1842, there will be a partial eclipse of the moon:—to what places will it be visible at the time of the middle of the eclipse, or five hours forty-five minutes P.M. (Greenwich): and how high will the moon then be at Calcutta, at the Cape of Good Hope, and at Botany Bay?

Here, first elevating the south pole to 18¾° (the sun's declination), bringing London to the meridian, and turning the globe eastward five hours and three quarters, I find that the Sandwich Islands, the Friendly Isles, and New Zealand, have all just risen into sunlight, and thus quitted their view of the lunar eclipse; whilst the south of East Greenland, Morocco, and the whole south-west coast of Africa, are just leaving sunlight to behold it. Next, elevating the north pole 18¾°, setting the index to twelve, turning the globe twelve hours, and screwing the quadrant to the zenith, the nut of the quadrant represents the moon; and its graduated edge applied to Calcutta, &c., gives (as in Prob. VII. p. 81) the altitude at which the eclipse is viewed from those places.

Ex. 2. From which parts of the earth's surface was the lunar eclipse of the 9th of April, 1838, visible at the time of middle eclipse, thirteen hours fifty-eight minutes (Greenwich); and if visible at London, at what altitude was the moon at that time there, and what at Paris and at Edinburgh?

Ex. 3. On the 3d of October, 1838, the moon was eclipsed; the first contact of the moon with the earth's penumbra occurred at 0 hrs. 11m., or eleven minutes past noon, Greenwich time; to what remarkable Indian city had she then very lately risen, and to what remarkable islands had she lately set?

Ex. 4. The middle of the last mentioned eclipse, was two hours and a half after its commencement (or two hours forty-one minutes P.M., Greenwich time):—what *then* were the moon's altitudes at Calcutta, at Madras, and at Botany Bay?

Ex. 5. The moon's last contact with the earth's penumbra, took place after two hours and a half more, (or at five hours eleven minutes P.M., Greenwich time,)—from what other remarkable places had she then, for some time, been viewed; and what, at this termination of the phenomenon, was her altitude at Pekin, at Petersburgh, and the Cape of Good Hope?

Ex. 6. From what places will the lunar eclipse of the 12th of June, 1843, be visible at the time of its commencement, supposing that to be at six A.M., Greenwich time?

Ex. 7. From what places may a part of the lunar eclipse of the 2d of June, 1863, be visible, supposing the middle of the eclipse to be at midnight, (Greenwich time,) the eclipse beginning two hours and three quarters before this time, and ending two hours and three quarters after it?

CYCLE OF THE MOON, GOLDEN NUMBER, EPACT, MOON'S "AGE."

F Meton, a Greek mathematician, (432 B.C.) discovered that 235 lunations comprise* nineteen years, and that, consequently, the same positions and phases of the moon recur with exactness on the corresponding days of any two of such periods. Honours were decreed to him for this discovery, and his computation was engraved in letters of gold. The *Golden Number* of our calendar, is the number indicating the years that have elapsed since the last completion of one of these cycles.

The year "*one*" of the Christian Æra, was the *second* year of a Metonic Cycle. Hence, if we add *one* to the date of the present year, and divide by nineteen, the quotient will shew the number of cycles completed since the Christian Æra, and what remains† will shew "*the Golden Number*," that is, how far we have advanced in the current cycle; or how long (including the present year) it is, since the moon had the first day of her lunation on the first of January.

Thus, the year 1842 has nineteen for its golden number;—a new moon will occur on the 31st of December, and the 1st of January, *1843*, will commence the ninety-eighth lunar cycle of the Christian Æra.

G *The Epact*, for any year, expresses the moon's age at its commencement.

Our average calendar year of 365¼ days is, very nearly, eleven days longer than the lunar year, or twelve lunations: hence, the Epact or moon's age at the commencement of the *first* year of a lunar cycle being 0 days, her age at the commencement of its *second* year will be 11 days, and at the commencement of the *third* year 22 days; but its fourth new-year's-day will have a moon of three days old, because she will then have passed 33 days, or three days more than a whole lunation:—the fifth new-year's-day of the cycle will have the moon 14 days old, &c. &c.

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* They exceed nineteen years by about an hour and a half only.

† If nothing remain, the year completes the cycle, or is the 19th.

In this way, the Epacts of a lunar cycle are 0, 11, 22, 3, 14, 25, 6, 17, 28, 9, 20, 1, 12, 23, 4, 15, 26, 7, 18.

H We may remember that at the beginning of the lunar cycle, or when the Golden Number is 1, the Epact is 0:—if we deduct *one* from the Golden Number of any year and multiply by 11, the product being divided by 30, what remains will shew the Epact.

Thus, in 1834, when the Golden Number was 11, the Epact was 20; and, in 1841, the Golden Number being 18, the Epact was 7.

K There is a monthly Epact, arising from the difference between the lunar month and the calendar one. We may find the age or phase of the moon with tolerable correctness for any time of the year, by adding the day of the month to the Epact for the year, or its 1st January, and an allowance of *one day* for every month since February.*

Thus, for the phase or age of the moon on 6th April, 1842:—

Six days for the date, *plus* 18 (or the Epact), *plus* 2 days (for two months elapsed since February), will give 26 days for the age of the moon on the 6th April. She will consequently be new again on the *fourth* day afterward, or on the 10th April.

For the age of the moon on 17th Oct. 1849:—

17 days + 6 (or Epact), + 8 days (for the months elapsed since February), = 31 days; that is, she will be new, or one day old, on 17th October, 1849.

CYCLE OF THE SUN.—DOMINICAL LETTER.

L The "Cycle of the Sun" has not, as might be supposed, any regard to the apparent ecliptic progress of the sun; but refers only to the circulation of the Sundays of 28 years amongst the first seven letters of the alphabet, which are attached, in their order, to every seven days of the calendar.

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* The surplus above a lunar month in January may be considered as compensated by the deficiency of February.

Since the common year consists of 365 days, or 52 weeks and one day over, that one of these seven letters which is attached to the *Sundays* of such year will be attached to the *Mondays* of the year first following it—to the *Tuesdays* of the second following year, &c. &c.:—so that, if all years contained this excess of one day only, the return of Sundays to the same letter would take place exactly every seven years; and any day of a period of seven years, as, for instance, the 989th or 765th, &c., would have the same letter in the calendar as the 989th or 765th, &c., day of the preceding seven years' period; but, because the February of every fourth year has 29 days, and the year 366 days, and therefore an excess of two days above the even weeks, the letters then *leap* * in the months after February; and four times seven years, or 28 years, are requisite for the return of the Dominical letters in the same order year after year;—that is to say, if we were to number, consecutively, the days of each of two periods of 28 years, any two corresponding days of the two periods would be found against the same letter notwithstanding the interference of leap-years.

M The chief use of the "Cycle of the sun" is to find the Dominical letter; but it is hoped that the following may be approved as a concise rule for finding, mentally, the Sunday letter of any year until A.D. 1900:—

Add the odd years and their fourth † part to *two*,—
A sum arises, which, if we review
How much it lacks of *sevens*, will give the station
The letter holds in alphabet rotation.

⁂ If the sum so found be an exact number of sevens, the Dominical letter is the *seventh*, or G.

Thus, for 1841—to the odd years, 41, add 10 (their fourth part, omitting fractions), and also the number 2, and the sum is 53; which, being 3 deficient of *eight sevens* or 56, shews the Dominical letter to be the *third*, or C.

For 1827, add 27 to 6 (its fourth part, disregarding fractions), and also the number 2, and the sum is 35; which being nothing deficient of even sevens, the letter is the *seventh*, or G.

For 1843, take 43 + 10 + 2 = 55; and since this sum is one deficient of even sevens, the Sunday letter is the *first*, or A.

For 1844 (leap-year), take 44 + 11 + 2 = 57; which being six deficient of 63, the next number containing even sevens, the letter is the sixth, or F (after February ‡).

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* Hence the term "*leap year.*"

† Disregarding fractions.

‡ N.B. In the January and February of a leap year, the Sunday letter is the next in alphabetical order to that which marks the Sun-

THE TIDES

" Are forced oscillations excited by the rotation of the earth in an ocean disturbed from its figure by the varying attractions of the sun and moon."—*Sir John Herschel.*

Philosophers in every former age have been puzzled to account for these phenomena.

Pliny, the Roman naturalist, A. D. 60, was led to attribute them to the action of the sun and moon, from their evident correspondence with the periods and phases of the latter luminary.

Kepler recognised the gravitating influence of the moon, alleging that if the earth could cease to attract the waters towards itself, all the waters of the ocean would rise and flow into the moon. Galileo rejected this doctrine, as did also our renowned countryman Francis Bacon. The honour of the discovery of the true theory of the tides is due to Sir Isaac Newton.

N We have seen (S and T, p. 257) that even the far separated planets exercise a disturbing influence on each other, in degrees proportional to their masses and the lessening of their mutual distances; and if we have received the assurance, which the fulfilment (Z, p. 220) of results predicted in reliance upon the existence of such influences ought to inspire, we shall be prepared to receive, with less hesitation, the theory upon which astronomers account for the phenomena of the tides.

P Although exerted at 400 times* the distance of the moon, the sun's attraction on the earth is very great compared with the moon's; for her mass is to his but as *one* to *twenty-seven millions!* But there is this important difference of influence resulting from her nearness; viz. that

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days of its following ten months; hence, in the chronological notes of the almanac for 1844, against the words " Dominical letter" will be found G F.

* It may be useful to repeat here, that if a common twelve-inch globe be taken to represent the *earth*, the *moon* may be fairly represented by a good-sized cricket-ball, or a three-inch pocket-globe, *at the distance of ten yards;* but the *sun* by a globe of a hundred and ten feet width (or such as might be made of two hemispheres like the dome of St. Paul's), placed *at the distance of two miles and a quarter!*

whilst, as we have seen (B, page 10), the earth's semi-diameter, or even her diameter, is almost insignificant when compared with the sun's distance, and the exertion of his great force is therefore scarcely different on those two parts of our surface which, at any time, may be nearest to him and farthest from him, the moon's distance from one such part of the earth's surface is as much as one-thirtieth greater than her distance from the other: the surface nearer to the moon is, therefore, attracted by her considerably more, and the surface more distant from her considerably less, than the earth's central parts. The phenomenon of the tides is chiefly owing to this difference of her attraction.

Q "The tides are a subject on which many persons find a strange difficulty of conception. That the moon by her attraction should heap up the waters of the ocean under her, seems, to most persons, very natural: that the same cause should, at the same time, heap them up on the opposite side, seems to many palpably absurd. Yet nothing is more true, nor indeed more evident, when we consider that it is not by her *whole* attraction, but by the *difference* of her attractions at the two surfaces and at the centre, that the waters are raised."—*Sir John Herschel's Astronomy.*

R If the earth were altogether a spherical mass of yielding fluid, like a ball of quicksilver, of her present size; that is, if it were a body of which the parts were moveable one among the other with entire facility, those parts would, on account of this disparity of attraction of the moon, be all differently affected:—the *sphere* would become a *spheroid*, with its longer axis directed towards the moon; and if the moon revolved in an orbit around it, as now she does, the particles of such spheroid would all be in continual commotion, each being impressed by that different force of the moon's attraction which would be due to its different distance from the moon, to take its place in forming this spheroid, whilst the spheroid itself, having constantly to adjust itself to the position of the moon as she moved eastward, could never be at rest. If, in addition to this, we suppose this spheroid to begin to rotate on an axis, we may understand that the commotion of its fluid particles would be rendered much more complex than before.

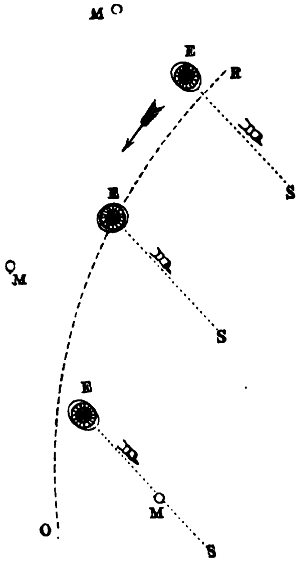
S Now the earth, although mainly a dense solid body (T, p. 173, *note*), has a fluid distributed over three quarters of its surface. The parts of this fluid at any time most distant from the moon are, of course, least of all affected by her; and thus the huge solid ball itself (attracted as if its whole mass were at its centre) is *drawn away* in a minute degree from those fluid parts, and they *so far* become *protuberant*. The fluid surface at the same time nearest to the moon, from its very mobility as fluid, is more at liberty than the solid bed on which it lies to obey the moon's attraction, and is thus still farther drawn towards her.

T " In fact, the earth is constantly falling to the moon, being continually drawn out of its path: the nearer parts more, and the remoter parts less, than the central; and thus, at every instant, the moon's attraction acts to force down the waters at the sides, at right angles to her direction, and raise it at the two ends of the diameter pointing towards her."—*Sir John Herschel.*

V We are, then, living on a globe the outline of the waters of which tends to a spheroidal figure; but we must remember that our dwelling-place is rotating on its axis whilst under this attracting and disturbing influence of the moon: —In consequence of their *inertia*, the waters *cannot* wait to perfect this spheroid; but having been affected by the moon's attraction to muster under her, they are carried past her, and go *forward* to attain their greatest accumulation.

" If the tides be considered relatively to the whole earth and open sea, there is a meridian about 30° *eastward* of the moon where it is always ' high water,' both in the hemisphere where the moon is, and in that which is opposite. On the *west* side of this circle (meridian) the tide is *flowing*, on the *east* it is *ebbing*; and on every part of that meridian which is 90° distant it is *low* water."—*Mrs. Somerville's Con. of Phys. Sc.*, p. 114.

W This great swell of the waters is sometimes augmented and sometimes diminished by the water of another swell of similar form raised by the sun; but which is much smaller, owing to the greatness of his distance, which, as before stated, is such as to render the width of our globe nearly insignificant; so that, unlike the moon, he affects all portions of our waters by nearly equal attraction. When the moon is in "syzygy," that is, on the same or on the opposite semi-meridian with the sun, and therefore "new" or "full," this solar wave combines with the lunar one, and we have our highest or *spring* tides; but when she is "in quadrature," or has 90° difference of Right Ascension, this small solar tide wave tends to fill up the interval between the two lunar ones, by robbing each of them of a portion of its mass; and we, consequently, experience our lessened or "*neap*" tides, which neither rise so high nor sink so low as the spring tides.



Let R O be taken to represent what might be the orbitual path o the earth if it were undisturbed by the moon. Then E (in the *upper* part of the cut) may represent the relative positions of the moon and earth at the time of "full moon," and the spheroidal form (necessarily much exaggerated) which the watery covering of E would assume whilst falling toward M (as described in S and T, p. 341).

In such a position, it is evident that the high water on the farther side of E from M is due, not only to its being less attracted and, as it were, left behind whilst E is being drawn away toward M; but also to the direct attraction of the opposite S (the sun, in the direction shewn by the index). In the position represented in the middle, the two high tides raised by M the moon (now in quadrature) are lessened by what is due to the direct attraction of the sun; for he evidently robs each of them, by partly filling up the interval and thus preventing the occurrence of so high or so low a tide as in the former case. In the third or lowest representation (of new moon), the two high tides are occasioned by the combined attractions of the sun and moon, and the result is like that first represented.

× The moon, in performing her monthly ellipse about the earth, is alternately at her greatest and least distance from us. When "new" or "full" at or near the time of her Perigee, her attraction being then most forcible, (if other circumstances do not exist to counteract it,) we have our spring tide much increased, and the succeeding spring tide (about a fortnight after, when she is in Apogee), considerably diminished.

Y The declination of the sun and moon, also, affects the mass of the tidal wave, since the effect of either of these bodies is greater the more nearly it coincides with the plane of our Equator. We have attended (in Prob. C,) to the moon's nodes, and have seen how the situation of these constantly shifting points affects her declination. The variation of the height of the tides must hence, in some measure, conform to a "cycle of the moon's nodes" (p. 307, note).

At the Equinoxes, or very near them, a spring tide would be the greatest possible if the moon's declination, like the sun's, were 0, and she were in Perigee.

Z But what has been thus introduced refers, properly, to a globe *covered* with water. The Caspian, the Black Sea, the Baltic, and even the Mediterranean *, have little or no sensible tides. "The disturbing action of the sun and moon can only become sensible in a very great extent of water: it is evident that the Pacific Ocean is one of the principal sources of our tides." Part of the great tide wave raised in the Pacific, obeying the motion impressed upon it by the rotation of the earth, is transmitted around South America and, proceeding northward up the Atlantic, at one time combines with the tidal wave of that ocean, and at another time opposes it. After being variously reflected by the shores of Africa and Europe, still coming northward, it " pours through the British and Irish Channels into the North Sea."

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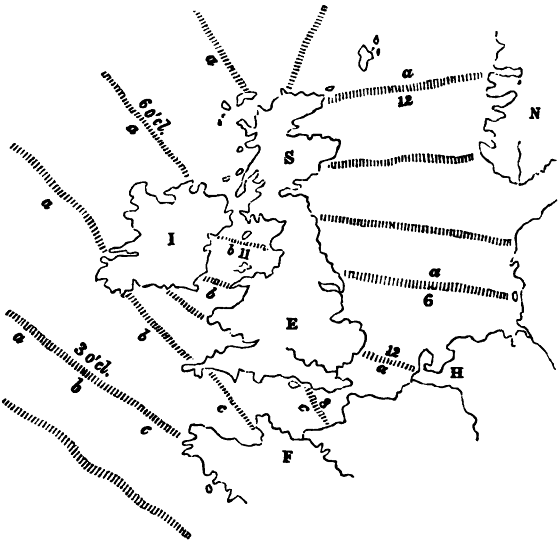
* When Alexander led his Greeks to the mouth of the Indus, in order to attempt to open an intercourse by sea between his Persian dominions and farther Asia, their astonishment was excited by the rise and fall of the tides. When the Romans, who, like the Greeks, had been acquainted only with the Mediterranean, first invaded the countries open to the Atlantic, the tides were an object of wonder and terror to them.



In the cut, let F, E, S, I, N, and H, represent France, England, Scotland, Ireland, Norway, and Holland, and *a*, *b*, and *c*, the tidal wave in its progress from the Atlantic, whence it may be supposed to have arrived at three o'clock, and to stretch, as drawn from the island Ouessant, on the coast of France, towards the north-west.

This portion of the great wave becomes divided, by the impediments of our coasts, into its parts *a*, *b*, and *c*,—one part passing up the British Channel, another making its way through the Irish Channel, and the third ranging in the more open sea, with greater rapidity, along Ireland's western coast. The first (*c*) flowing through the British Channel, at eight o'clock will have proceeded to the Isle of Wight and, passing through the Straits of Dover, will reach the Nore about twelve at night. The second (*b*) by eleven at night, will nearly have reached the north-east coast of Ireland. The third (*a*) being in the more open sea, as early as six o'clock will have reached the northern extremity of the Irish coast; by about nine arriving at the Orkneys and forming a ridge or wave, extending due north. At twelve the summit of the same wave will extend from the coast of Buchan eastward, to the Naze of Norway; and in twelve hours more, having dispensed "high water" to Denmark, Holland, and the various ports of our eastern coast, it will reach the Nore and meet the morning tide just arriving from the Atlantic.*

B "On the coast of France, and in the British Channel, the highest spring tides are about two days after "Syzygy," but at London they are later, for the tides at London are caused by the wave (as *a*) which descends along the eastern coast of Great Britain, and which meets off the coast of Kent, a tide produced twelve hours later."—*Treatise on the Tides, by J. W. Lubbock, Esq., p.* 29.

Thus "the tides on the shores of the Atlantic, which are afterwards propagated around Great Britain, must be considered as due to the attraction of the luminaries at the time of a distant transit:—For example, the tide at the London Docks on Wednesday afternoon, is produced (in the Pacific Ocean,) by the attraction of the luminaries on Monday morning."—*Lubbock*, p. 28.

C "A flood arriving at the mouth of a river, must act precisely as the great wave does. It must be propagated up the river in a certain time, and we shall have high water at all the different places in succession. This is distinctly seen in rivers. The most remarkable instance of this kind, is the Maragnon or Amazon river, in South America. It appears from the observations of Condamine and others, that between Para, at the mouth of the river, and the conflux of the Madera and Maragnon, there are *seven* coexistent high waters, with *six* low waters between them. Nothing can more evidently shew that the tides in these places are nothing but the propagation of a wave."—*Encyclopædia Brit.*

D The tide wave of the German Ocean, or our eastern coast, takes twelve hours to travel from the mouth of the Thames to London Bridge; consequently, by the time of its arrival at London, there is a new tide at the mouth of the Thames and low water nearly midway to London.

F There are frequent irregularities in the height of the tides, arising from strong winds, heavy rains, and land floods. A strong gale, acting at the distance of hundreds of miles on the crest of the wave as it is still travelling in the open ocean, will evidently affect the arrival, as well as the height, of a tidal wave, derived from that quarter. The breadth of a channel or river, as well as its constantly changing bed, its banks, its shallows, its sinuosities, materially affect the time, as well as the height of the tide. "It would appear that high water at London, at full and change of the moon, was A.D. 1213, more than an hour later than at present."—*Lubbock.*

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* See *Familiar Lectures on Astronomy*, by the late Mr. William Phillips, F.L.S.

G The high water mark at London, is between twenty-two and twenty-three feet; but the sea is so pent up in the British Channel, that the tides sometimes rise as much as fifty feet at St. Malo (coast of France). At Annapolis, (west coast of Nova Scotia,) the tide is said to rise 120 feet; whereas, on the shores of some of the South Sea islands it does not exceed eighteen inches or two feet. The tides are barely perceptible in very high latitudes, and probably do not reach the poles.

Recapitulation.

H Suppose it to be six o'clock on Monday evening, and the moon just to have completed her first quadrature, and therefore to be on our London meridian at this time:—We may remember that about twelve hours twenty-five minutes before this, she was crossing the *lower* meridian, and was therefore vertical over a spot in the midst of the Pacific Ocean. The whole of the waters of that vast expanse were then, by the interfering attraction of the moon, disturbed from that outline to which the attracting force of the earth's whole mass is ever enticing them; and, at that moment, each drop or particle may be said to have been impressed with an inclination, strong in proportion to its nearness to the spot over which she was shining, to make its way towards that spot, and thus to help to form an ocean with an oval outline, the highest part of which should be underneath the moon. But meanwhile, each drop was compelled to obey also the earth's rotation; and that too, as the pupil knows, with a velocity in accordance with its particular latitude; so that the exact place in the oval outline, which the attraction due to each drop's individual distance from the moon would have led it to assume, could not be taken by it; and in addition to this, the precise spot towards which the water had been attracted was no longer the spot of attraction, for, in consequence of the earth's rotation, the moon was only for an instant in the zenith there.

The whole consequence of these circumstances, was the production of "an immensely broad and excessively flat wave (not a circulating *current*). * * * * When the higher or lower parts of this wave strike the coasts, they experience what we call high or low water."*

K The question arises, what became of this state of disturbance of the equilibrium of the ocean so caused? Has it yet subsided? It has not, for the same cause that the vibrations of a pendulum cannot at once subside—the existence of *inertia* (D, p. 207). The undulations of the body of water so raised, are even now being propagated, by impression from body to body of the waters of our globe. The moon which now, (Monday, six P.M.,) is beginning similarly to trouble the less expanse of the Atlantic, (to the middle of which she will be vertical in two hours' time,) beholds the consequence of her morning work in the Pacific, in the transmission of a portion of the swell she then caused around Cape Horn, into the Atlantic; and she may view it, during her operations of the next four hours over that sea, at one time combining with and augmenting, at another time tending to oppose and efface, that very wave which is the immediate consequence of her present attraction there.

L The great tidal wave is of course imperceptible to those who may be navigating its surface, except near the shores, on account of its great extent and excessive flatness; for it stretches from Africa to America, and dispenses high water to the shores of each; but it will still hold on its

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* Sir John Herschel.

northward way with great velocity, (preceded and followed,[*] at equal pace, by similar waves of earlier and later origin,) until having, on Tuesday afternoon, reached the north-western coast of France, its eastern edge will find an interruption on the southern coasts of Great Britain and Ireland, and divide into portions, which will proceed (at different rates, because of the difference of impediment,) up and around the coasts of our islands, to lift the cargoes of our ships and furnish, at London, the Wednesday business of our wharfs with its "nerves and sinews."

"ESTABLISHMENTS" OF DIFFERENT PORTS, ETC.

M The moon, if new or full at the noon or midnight of any place, must be crossing the plane of the meridian of the place at that time. The interval between such a culmination of the moon at any port and the next "high water" there, is called the *establishment* of that port:—The establishment of London is about two hours.

But although it is usual thus to refer the time of high water to the transit of the moon next preceding it, as if her latest approach were the immediate cause of the phenomenon, such is not the case, as we have seen; for as she ceases to have any sensible influence on the tidal wave after its arrival in the narrower seas, in a river like the Thames both the present swell, and that which will be its successor after the lapse of another twelve hours, must already have travelled a considerable distance unchanged by the attraction of the moon, even before the time of her rising.

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[*] The pupil will need again to be reminded, that it is not so much the body of water that travels, but the impression of its motion that is propagated or communicated (see G, p. 207).

Mr. Lubbock, who, as well as Mr. Whewell, has been much occupied in investigations on this intricate subject, gives* a table, from which the following is extracted, referring to the operations of the sun and moon at various angular distances from each other, and under average circumstances of declination, nearness, &c.; but *at an interval of more than two days before* the effect of those operations is discerned in London river in the flow of our "tide."

TABLE.

The angular distance of the sun and moon from each other, may be inferred from the time of the moon's coming to the meridian. The interval given shews, when added to the time of the moon's culmination, the time of high water at the *London Docks*:—*ten minutes more* are to be added for the time of high water at *London Bridge*.

Time of ☽ 's transit.	Interval.	Height in feet.	Time of ☽ 's transit.	Interval.	Height in feet.
h. m.	d. h. m.		h. m.	d. h. m.	
12 . 0	2 . 3 . 16		6 .	2 . 2 . 56	
12 . 30	2 . 3 . 7	22¾	6 . 30	2 . 3 . 11	19½
1 .	2 . 2 . 59		7 .	2 . 3 . 27	
1 . 30	2 . 2 . 51	22½	7 . 30	2 . 3 . 42	20
2 .	2 . 2 . 43		8 .	2 . 3 . 50	
2 . 30	2 . 2 . 36	22	8 . 30	2 . 3 . 53	20¾
3 .	2 . 2 . 30		9 .	2 . 3 . 52	
3 . 30	2 . 2 . 26	21½	9 . 30	2 . 3 . 50	21½
4 .	2 . 2 . 24		10 .	2 . 3 . 45	
4 . 30	2 . 2 . 24	20½	10 . 30	2 . 3 . 38	22¼
5 .	2 . 2 . 29		11 .	2 . 3 . 31	
5 . 30	2 . 2 . 38	20	11 . 30	2 . 3 . 23	22½

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* See "*Elementary Treatise on the Tides*," *by J. W. Lubbock, Esq., Treas. R. S.*

PROBLEM M.

CELESTIAL GLOBE.

To find the time of high water at the London Docks, or certain other places, on a given day.

RULE.—1. Find the time of the moon's "southing" at Greenwich on the day next but one before the given date.

2. Look out, in the left-hand column of the little table given on p. 349, for the time agreeing most nearly with this time of the moon's southing, and against it will be seen the interval to be added to shew the time of high water at the London Docks on the given day.

⁂ If the time of the moon's southing, so found for the day next but one, was in its forenoon, and the addition of the interval produces more than two days twelve hours, the excess will, of course, shew the time of high water in the *afternoon* of the proposed day; but if the moon's southing was of the afternoon, and the addition of the interval produces more than two days twelve hours, the excess shews the time of high water *in the morning of the day succeeding the proposed one*. The time of the preceding tide may be found nearly, by deducting twelve hours twenty-five minutes.

Ex. 1. What was the time of high water at *London Bridge* on the 22d June, 1841, the moon having "southed" at nineteen minutes past one P.M., of June 20th?

Here, looking in the table for the *nearest* time, I take the interval placed against *one hour thirty minutes*, and adding it to one hour nineteen minutes, I get two days four hours ten minutes, shewing the time of high water at the *London Docks* on the 22d of June, to be ten minutes past four P.M. I afterwards add ten minutes to this for the time of high water at *London Bridge*, and the result differs only nine minutes from the time given in the ephemeris.

Ex. 2. Find the time of high water at London Bridge on the 2d of July, 1841; the moon having "southed," or ome to the meridian of Greenwich, on the 30th of June, t nine hours forty-three minutes P.M.

I find in the table against ten hours, the interval of two days three ours forty-five minutes; and adding it to nine hours forty-three inutes, I get two days thirteen hours twenty-eight minutes. This akes me to the 3d of July, one hour twenty-eight minutes A.M., for igh water at the London Docks, and one hour thirty-eight minutes,* or high water at London Bridge. The high water of the afternoon f the 2d of July, was twelve hours twenty-five minutes before this, r at one hour thirteen minutes P.M. (very nearly).

Ex. 3. What was the time of high water at the *London Docks*, and what was its height there, on the 24th of September, 1841, the moon having culminated at six ours P.M., on the 22d of September?

Ex. 4. What was the time of high water at *London Bridge* on the 5th of December, 1841, the moon having 'southed" at four hours two minutes A.M., on the 3d of December?

Ex. 5. What will be the time of high water at London Bridge, on the 27th of December, 1841, the moon "southing" at nine hours thirty-eight minutes in the afternoon of Christmas day? (see ⁂ following the Rule.)

Ex. 6. The moon's longitude on the 7th of August, 1841, was 11° ♈ 28′; at what time† did she culminate on the 8th of August, and what was the time of high water at London Bridge on the 10th of August?

Ex. 7. The moon's longitude on the 30th of August, 1841, was 19° ♒ 34′; at what time was her southing on that day, and what was the time and height of high water at the London Docks on the 1st of September?

The time of high water at London Bridge being ascertained, the times of tide at other places are to be found by the addition or deduction of certain differences given in "tide tables;" but local circumstances frequently occasion irregularities, and no such table can predict correctly for every given place.

Thus, having the time of high tide at London Bridge, for the time of high water at

		h.	m.
Brighton	*sub.*	3 .	1
Cowes	*sub.*	3 .	31

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* Within eight minutes of the true time, as given in the almanac.

† The southing must be found by Problem D, p. 312.

		h.	m.
Dover Harbour	*sub.*	2	52
* Flamborough Head	*add*	2	0
Gravesend	*sub.*	0	54
Hull Dock Gate	*add*	4	8
* Land's End	*add*	2	0
Liverpool	*sub.*	2	45
Lowestoff	*add*	7	20
Margate Roads	*sub.*	2	52
Nore	*sub.*	1	9
Portsmouth Harbour	*sub.*	2	27
Shields	*add*	0	20
Woolwich	*sub.*	0	25
Aberdeen	*sub.*	1	22
Leith	*add*	0	13
Cork	*add*	2	25
Dublin	*add*	5	0
Boulogne	*sub.*	3	37
Brest	*add*	2	23

Ex. 8. Find the time of high water at London Bridge, on the 19th of May, 1841, the moon having "southed" there at eight hours and three quarters A.M., of the 17th; and from this high water determine, by the differences given in the above list, the times of high water on the 19th, at the undermentioned places:—

Liverpool
Margate
The Nore
Brighton
Brest
Gravesend
Land's End
Flamborough Head
Leith
Cork

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* In reading over the above table carefully, the pupil will perceive that *Land's End* and *Flamborough Head*, have high water at the same time; this is evidently owing to different tidal waves, that of Land's End being of later origin. (See cut on page 344.) It will be seen also, that the time of high water at *Margate* corresponds very nearly to that of *Liverpool;* but this is the *same* high water, that is to say, the two places are supplied at the same time, by the one wave which, arriving from the Atlantic at our southern coast, divides into parts, of which one, proceeding up St. George's Channel, reaches Liverpool by the time that another part proceeding up the English Channel (and having passed Deal, &c.) arrives at Margate.

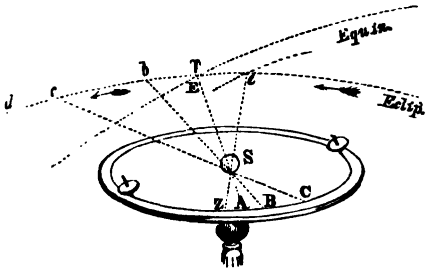
PRECESSION OF THE EQUINOXES.

SIDEREAL YEAR.—SOLAR YEAR, ETC.

We must again advert to the two planes of our table and button (p. 108), and the markings out of these planes on the wall, as representing the equinoctial and ecliptic in the sky;—♈ E being their intersection, and representing, as before, the *vernal equinox*.

N It is stated in the lower half of p. 253, and in N, on p. 254, that the oblateness of Jupiter's shape affects the motions of his satellites. In like manner, the oblateness of our rotating earth affects our moon; the attraction of the protuberant matter of the equatorial regions causing inequalities in her latitude, and, to a small extent, also alternately augmenting and diminishing the inclination of her orbit to our ecliptic. Astronomers have even calculated from these lunar inequalities, not only the compression of the earth's spheroid, but also its increase in density towards the centre (2 of p. 260).

P But action and reaction are equal, and comparatively small as the mass of the moon is, those variations in her attraction on the earth's mass which are due to her being each week variously situated with respect to the slight protuberance of the equatorial regions, combined with the sun's variation of position with regard to those regions, have been productive of circumstances involving results of great historical interest.



P If our table were to remain unmoved, and the te-to-tum button also were undisturbed during any number of times of its traversing the circumference of the table, the equinoxes, or intersecting points, would of course remain undisturbed also. But if anything should influence the button plane whilst thus performing its 366 rotations, and completing its circuit upon the table, so as to tend to *tilt* its edge and make it reel, ever so slightly, there must be a corresponding effect produced upon the lines on the wall with regard to their intersections.

We know (K, p. 108) that it is from a point in the sky, represented by the intersection ♈ E, that astronomers reckon in assigning places to the heavenly bodies. The oblique attractions of the sun and moon upon the redundant matter accumulated about the earth's equator, cause a tendency to *reel* in the equatorial plane, and therefore such a change in the equinoctial intersection in the heavens.

Q The ball in the middle of our table, representing the sun, would seem, to the inhabitant of our te-to-tum, to be on the wall at the intersecting point ♈ (and with any star at that point) when the te-to-tum was exactly at A, and the ball just intervened between A and E. Now our earth, so represented, is found to traverse its orbit from A, (where its inhabitants have the sun or ball with the star at E,) along the orbitual path A B C &c., (represented by the groove,) around to A again, in exactly 365 days, 6 hours, 9 minutes, 9 seconds; the sun (or ball) seeming, in consequence, to pass along the ecliptic line E, *b*, *c*, *d*, &c., (on the round wall,) to E again. But in doing this, it really ***will already have passed*** the equinoctial point, for that point is not now at E, but at (*e*), and the sun (or ball) will have appeared at (*e*), whilst yet our te-to-tum earth was at Z, not having completed its orbitual path in the groove to A, by twenty minutes twenty seconds. Still, as the equinoctial intersection, although thus removed, is the reckoning point, this shorter period will be the *Solar year*, consisting (as may be seen by subtracting the twenty minutes twenty seconds deficiency) of 365 days, 5 hours, 48 minutes, 49 seconds. The whole revolution which brings the sun again to a star at E, the former place of the equinox, is the *Sidereal year*.

R The direct tendency of this disturbing influence of the sun and moon, is to bring the planes of the equator and ecliptic to coincide; but the *spinning* of the earth on its axis resists this and preserves their inclination, and, with it, the periodical changes of our seasons, and all the blessings they bring us. The chief result being, as we have seen, *the precession*, or rather *recession*,* *of the equinoxes*, "a continual retrogradation of the node of the earth's equator (equinoctial) on the ecliptic." The entire recession of ♈ E, from the cause just noted, is about $50'' \frac{41}{100}$ annually; but we have before seen (S and T, p. 257) that the ecliptic itself, like the orbitual plane of every other planet, is under a disturbing influence from the fellow members of the whole system; and from this cause, the equinoctial points are affected with a contrary, or direct tendency, at the rate of $\frac{31}{100}''$, so that the mean annual recession of ♈ E, is the difference of these, or $50'' \frac{10}{100}$ only,—amounting to 1° in 72 years.

S The pupil will readily understand that one effect of this slow, but constant, motion of the point from which the *right ascension* and *longitude* of a star are reckoned, is a change of those quantities themselves as assigned to that star; and accordingly, it is only *now* that the sun of the 20th of August is with Regulus, or that that star will cross our meridian when the sidereal clock (def. 53) is shewing nine hours fifty-nine minutes.

T But the *declination* of a star is also changed;—for, as the equinoctial preserves its inclination whilst thus shifting its points of intersection of the ecliptic, it must, in time, come to lie over totally different stars; and thus, in the lapse of years, or rather of centuries, some stars will become north of it which formerly were south of it; and others, now of south declination, will have north declination; the celestial pole or point, to which our te-to-tum peg or axis is directed, varying of course, in exact accordance, since it must always be 90° distant from every part of the equinoctial plane. Now we have learned, from various problems, how much the declination of a star affects its diurnal arc in any given latitude; and thus, the times of the rising and setting of stars is very different at present, from those recorded in ancient astronomical allusions.

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* *Recession*, if we speak of "the equinox" as the intersection merely: *precession*, if we refer to the *time* of the sun's arrival at the intersection.

U The phenomenon of precession may be explained as a conical motion of the earth's axis, "in virtue of which it points successively to every part of a small circle round the pole of the ecliptic." Its "visible effect" on the aspect of the heavens, consists of a slow forward apparent motion of every star *along* its parallel of latitude, for since the ecliptic and its pole are undisturbed by precession, the latitude of the star is unaltered by it. If we look at the lines of celestial latitude on the celestial globe, we shall see how declinations, as well as right ascensions, are affected by this.

V About 1300 years B.C., the star κ in the tail of Draco was very near the Polar point. The star of second magnitude in the tail of the Less Bear,—which, on account of its being a prominent one, and at the distance of 1½° only from the vanishing point of the earth's axis, we call the Pole Star,—at the date of the earliest catalogues of the stars, had the earth's axis directed 12° away from it. The axis will continue to be still more nearly directed to this star, until it points within ½° of it; and the same slow change of the pointing of the axis, continued for nearly 13,000 years from this time, would* cause it to be directed to within 5° of *Vega* (α of Lyra).

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[*] 2 Peter, 3 chap. (10-13.)

Ancient familiar allusions to the Risings and Settings of particular Stars.

W "The Greeks seem early to have seen the superior accuracy and determinateness of the celestial phenomena. In the didactic poem of Hesiod, this mode of marking the times of navigation and of rural labours is frequently employed; and its use was retained by the country-folk of both Greece and Italy far into the time of the Roman empire. Those who wrote on rural subjects or natural history, employed it: we meet with it in Aristotle, as well as in Pliny and Columella."—*Keightley's Edition of Ovid's Fasti. (Introduction*, p. xiv.)

X "The (Latin) poets teem with allusions to them, so much so that many passages must be unintelligible without we know the times at which certain stars or constellations, more particularly Capella, Arcturus, the Pleiades, and Orion, rose and set *heliacally* and *acronychally* at those times and for those countries."—"*Astronomy,*" *Library of Useful Knowledge*, p. 169.

Y * * * "Rain, wind, and other aërial phenomena were held to be connected with the rising and setting of various signs; the times of their risings and settings, both apparent and real, were computed by Meton, Eudoxus, and other ancient astronomers. The tables thus constructed were cut on brass or marble, and fixed up (whence they were called *παραπήγματα*) in the several cities of Greece, and the peasant or sailor had only to look on one of these *parapegmata*, to know what sign was about to rise or set, and what weather might be expected. Without considering the difference of latitude and longitude,* the Romans borrowed the *parapegmata*, like every thing else, from the Greeks. The countryman, as we learn from Pliny (xviii. 60, 65), ceased to mark the stellar heavens; a *kalendarium rusticum siderale (Colum.* ix. 14) taught him when the signs rose and set, and on what days he was to expect sacrifices and festivals."—*Keightley's Ed. Ovid's Fasti. Introd.*

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* The longitude could make no difference.

COSMICAL, ACRONYCHAL, AND HELIACAL RISINGS AND SETTINGS.

[z] Stars are said to rise or set *cosmically* * when they rise or set at sun-rise.

Stars are said to rise or set *acronychally* † when they rise or set at sun-set.

Those stars which, during the past month, have been visible above the western horizon each succeeding evening for a shorter time than its preceding one, will be said to set *heliacally* ‡ when, a few days hence, they first cease to be visible because of the sun's arriving into that part of the ecliptic from which, even as late as at their time of setting, his evening twilight can overpower them.

Stars are said to rise *heliacally*, when, after having hidden them in the splendour of his rays, the sun first gets so far eastward of them as that his morning twilight can no longer overpower them at their rising.

The *Cosmic* relates to the morn ;
Acronych, to sun-set or " first night ;"
Heliac, at eve or at dawn
The horizon's condition in light.

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* *κοσμος*, the distribution or order of things—the world.

† *ἀκρόνυξ*, *prima nox*, the beginning (one end) of the night.

‡ *ἡλιακος*, solar.

PROBLEM N.

CELESTIAL GLOBE.

Given the latitude, to find the time of year at which a particular star now rises or sets cosmically, acronychally, or heliacally.

RULE.—Rectify the globe for the given latitude, and attach the quadrant to the declination in the zenith: Then,

I. *With regard to a given star at its rising:—*

Bring the star to the eastern, or rising, edge of the horizon;—and, keeping the globe from rotating,

1. Look for the degree of the Ecliptic rising with the star:—this will shew the day on which (in the present age of the world) the star rises *cosmically*.
2. Find, by the quadrant, that degree of the Ecliptic which is only 12 * degrees below the eastern horizon:—this will shew the day on which the star rises *heliacally*.
3. Look for the degree of the Ecliptic coinciding with the western or setting edge of the horizon:—this will shew the day on which the star rises *acronychally*.

II. *With regard to a given star at its setting:—*

Bring the given star to the western, or setting, edge of the horizon;—then, keeping the globe from rotating,

1. Find, by the quadrant, that degree of the Ecliptic which is 12* degrees below the western horizon:—this will shew the day on which the given star sets *heliacally*.
2. Look for the degree of the Ecliptic setting with the star:—this will shew the day on which the star sets *acronychally*.
3. Look for the degree of the Ecliptic in the eastern horizon:—this will shew the day on which the star sets *cosmically*.

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* If the given star be only of the second magnitude, 13 degrees, &c. (see page 133).

Ex. 1. At what time of year does Aldebaran now rise cosmically, at what time heliacally, and at what time acronychally, at London?

Answer. Cosmically, 18° ♊ (8th June)—heliacally, 15° ♋ (7th July)—acronychally, 17° ♐ (8th December).

Ex. 2. On what day of the year does Aldebaran now set heliacally, on what day does it set acronychally, and on what day cosmically, at London?

Answer. Heliacally, 14° ♉ —acronychally, 2° ♊ —cosmically, 3° ♐.

Ex. 3. On what days of the year does Sirius now rise at Rome (latitude 42°), cosmically, heliacally, and acronychally?

Ex. 4. On what days do these several risings of Sirius take place at Alexandria (lat. 31°)?

Ex. 5. On what three days does Spica (α of Virgo) set heliacally, acronychally, and cosmically, at Madrid?

Ex. 6. In the evening of what day might Antares be seen to set for the last time, in a clear horizon, in lat. 51½° N.; and in the morning of what day will it first be seen in that latitude, after having been involved in the sun's rays? (See Z, p. 358.)

Ex. 7. For how many days longer is this star (Antares) visible in the evening at Madrid than in the latitude of London?

Ex. 8. What are the cosmical and acronychal risings of Castor at Edinburgh and at Gibraltar?

Ex. 9. On what day does δ (in Orion's girdle) rise cosmically at London; and how many days after will it be sufficiently removed from strong twilight to be seen at its rising, in the morning? (See note on last page.)

Ex. 10. On what day, at Greenwich, does δ in the girdle of Orion rise at sunset; and at what altitude will it be when the sun on that evening becomes 13° depressed, and the whole constellation may be plainly discernible?

Exercises concerning the effect of Precession on the places of the Stars in relation to the Equinoctial and its Poles, the Equinoxes, Solstices, &c.

I. *With regard to their Longitudes* :—

Since the lines of celestial longitude (drawn from the ecliptic and converging in the pole of the ecliptic) all refer to the intersection at the first point of Aries, the consequence of the westward or retrograde shifting of this point is a westward shifting of each of these lines also; and, therefore, an apparently forward motion of the stars themselves along their several parallels of latitude; hence,

Rule.—The number of degrees of any proposed change in a star's longitude multiplied by 72 (R, p. 355), will shew the number of years occupied in producing that change. Or,—If the time be given and the change demanded, the longitude will be 1° less for every 72 years elapsed, or 1° greater for every 72 years to come.

Ex. 1. How long is it (nearly) since the two remarkable stars in the Goat's head had longitude 10 signs passing through them; and how many years hence will their longitude become 10s. 5°?

Answer. Their longitude at present is 10 signs $1\frac{1}{2}$° :—hence, on a celestial globe constructed 72 years × $1\frac{1}{2}$, or 108 years ago, these stars must have had longitude 10 signs passing through them; and in 72 yrs. × $3\frac{1}{2}$, or about 250 years hence, their longitude will be 10 signs 5°. The pupil may readily perceive that, when this time shall come, not only their times of culmination must be different, but that their declinations also will be a little less south, and their diurnal arcs, &c., consequently altered in any given latitude.

2. What is the present longitude of the chief of the Pleiades; and what will be its longitude in about seventy-two years?

Ex. 3. What was the longitude of β of Aries about 80 years ago; and what will be the longitude of α of Aries as aid down on a globe published about 36 years hence?

Ex. 4. How long is it since the star β of Aries had lon-itude 0, and the Equinoctial point ♈ was consistent with ts constellation?

Ex. 5. Look at Algenib (γ of Pegasus) and α of Andromeda; observe their present positions with respect to the Equinoctial colure; and state what you judge would be the difference of their positions with regard to that line on a globe made in 1741.

Ex. 6. Refer to α and ζ of Perseus, and state how you would expect to see them in longitude on such a globe as that just mentioned.

Ex. 7. There will be a time when longitude 5 signs will have shifted back to coincide with Regulus; and when, consequently, that star, instead of being with the sun on the 20th August, will be with him on the 23rd August:—how long hence will this be?

Ex. 8. How long[*] is it, think you, since Castor came to the meridian with the sun on our 7th July?

Ex. 9. How long must it be before γ of Boötes will have the same longitude that δ of Boötes now has?[†]

Ex. 10. According to certain Chinese authors, Tcheou Kong, Regent of China, 1100 before Christ, observed that the R. A. of the Winter Solstice exceeded by 1° 58¼′ that of the star* now marked ϵ in Aquarius:—Is there reason, from this, to give credit to the Chinese record?

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[*] Castor is near the ecliptic, otherwise we should not have put the question in this form; because, as precession causes a change in the polar point, the globe would require to be differently suspended.

[†] NUTATION may be noticed here.—It has been mentioned that the precession of the equinoxes, the effect of which is this slow apparent motion of a star in longitude, is mainly caused by the undue attraction of the moon upon the equatorial regions. As far as γ of Boötes, for instance, is affected by precession, it apparently proceeds *along* its parallel of latitude (50°); but the star is found also to have an apparent oscillatory motion, so as alternately to deviate a very minute quantity, first on one side of its parallel and then on the other side of it, in the course of nineteen years. The pupil will recollect that this is the period of a cycle of the moon's nodes (*note*, p. 307); and, accordingly, the phenomenon is traced by astronomers to the varying positions of the lunar orbit, as presenting the moon's attractive force to the earth somewhat differently throughout that cycle.

As precession is conveniently referred to a motion of the earth's axis, as if it slowly revolved about a cone, so the additional phenomenon of nutation (a *nodding*) is referred to the same cone; as if whilst the earth's axis so revolved about it, it were finely fluted from the vertex to the base, and thus caused the axis to have also a tremulous or "nodding" motion.

II. *With regard to the effect of precession on Declinations, Diurnal Arcs, &c.*

RULE.—Still using 72 as the number of years required for the change of one degree in the longitude of a star, if the proposed number of degrees of change be multiplied by 72, the time will be shewn; and the declination may readily be found (nearly) by a consideration of the relative positions of the Equinoctial and the longitude proposed.

Ex. 1. When had α of Piscis Australis (Fomalhaut) the longitude that β of that constellation has now; what then was its declination, and did it then spend a longer or a less time above the horizon in our latitude?

Here, since the longitude of Fomalhaut must have changed about six degrees, about 430 years must have elapsed. The declination of the star β is about 2½° more south than the present declination of α:—hence, since 430 years ago, Fomalhaut held the same position with regard to the southern pole of those days, that β now has with regard to the present one, Fomalhaut spent rather less time above the horizon of London than it does now.

Ex. 2. When γ of Boötes shall have the same longitude that δ of Boötes has now, what will be its declination; and how far removed from the present north polar point of the heavens will the north polar point of that age be?

Ex. 3. What is the present diurnal arc of γ of Boötes at Greenwich, and what will it be when it shall have declination like that of δ of Boötes? (Prob. VI. p. 78.)

Ex. 4. How long is it since 1° ♎, or the point of the Autumnal Equinox, crossed the ecliptic in the longitude of η of Virgo;—what is the present declination of that star, and what was its declination then?

Ex. 5. Refer to Dubhe (α of Ursa Major);—find how long it is since its longitude was only 4 signs, and state what its declination must have been then, and how much farther, consequently, it was from the zenith of latitude 60° when culminating in those days, than it is at present?

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* Above the neck of Capricornus, and nearly half-way between α of Capricornus and β of Aquarius.

Ex. 6. How long is it since the equinoctial crossed the ecliptic in that point which is now marked 19° ≏:—what then was the declination (nearly) of ζ of Virgo; what is now its diurnal arc; and what was it then* in latitude 56° N.?

Ex. 7. When, (as last proposed) the autumnal equinox passed through our present 19° ≏, what was the declination of Spica (nearly), and did it then spend a longer or a shorter time above our horizon?

Ex. 8. When the Equinoctial shall cross the ecliptic in 19° ≏, what will be the rising and setting amplitude of ζ of Virgo at the equator, since there the amplitude always equals the declination?

Ex. 9. There was a time very near that referred to in the question just given, when the autumnal equinox coincided with the present longitude of Arcturus:—was this earlier or later, and what was the declination of Arcturus then (nearly)?

Ex. 10. At what distance from the present polar point, was the pole of those days (U and V, p. 356); and—since no northern star can be seen in a southern latitude greater than its co-declination,—beyond what south latitude could not Arcturus then have been seen?

Ex. 11. How far beyond the south latitude just found may Arcturus now be seen; and to what north latitude does that star now rise and set, to which, in the age just found, it was constantly above the horizon?

Ex. 12. Tracing from α of Lyra, eastward along its latitude (above parallel 60°) to the solstitial colure, (long. 3 signs,) we go over the path of that star's apparent change of position as caused by the precession of the Equinoxes, during many thousands of years. But, as we may see, it will thus become the pole star:—what will have been its change of longitude, and how many years must elapse from the present time, before the very slow change in the pointing of the earth's axis shall have accomplished so great an alteration in the apparent positions of the stars?

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* ζ of Virgo had then the diurnal arc that any star now has which has declination like that which ζ of Virgo then had.

On the application of Astronomical Observation, &c., to Chronology.

"Many ages of the world elapsed before the mode of computation by dating events was generally adopted. Even in Herodotus and Thucydides, we find no regular dates for the events recorded in their histories * * *

"The chronology of the early parts of history is full of uncertainty. Even after the adoption of dates, we find the early historians very inaccurate in their computations. Ancient chronology is a long perspective, bounded by impenetrable clouds, which are thinly chequered with a few glimmerings of doubtful light. In the fabulous and heroic ages precision is not to be expected. But lamentable is the uncertainty respecting some of the most important parts of history, such as the number of years elapsed since the Creation, the origin of the Chinese empire, the Egyptian dynasties, the reign of Sesostris, the rise and fall of the Assyrian empire, the chronology of the kings of Babylon, of the Median monarchs, and even of the successors of Alexander the Great."—*Introduction to Valpy's Poetical Chronology.*

But, besides the assistance given to chronology by the transmission of dates of many important events by medals, monuments, and their inscriptions, the uncontroverted eras of the *Deluge*, the Greek *Olympiads*, the foundation of *Rome*, the birth of Christ, the Mahometan *Hegira*;—

A recorded "astronomical observation of any striking and well marked phenomenon, carries with it, in most cases, abundant means of recovering its exact date, when any tolerable approximation is afforded to it by chronological records; and so far from being abjectly dependent on the obscure, and often contradictory, dates, which the comparison of ancient authorities indicates, is often itself the surest and most convincing evidence on which a chronological epoch can be brought to rest. Remarkable eclipses, for instance, now that the lunar theory is thoroughly understood, can be calculated back for several thousands of years, without the possibility of mistaking the day of their occurrence."—*Sir John Herschel, Ast., p.* 414.

"The ancient state of the heavens may now be computed with great accuracy; and by comparing the results of calculation with ancient observations, the exact period at which they were made may be verified if true, or, if false, their error may be detected." * * *

"The places of the fixed stars are affected by the precession of the equinoxes; and as the law of that variation is known, their positions at any time may be computed."

"It is possible that a knowledge of astronomy may lead to the interpretation of hieroglyphical characters. Astronomical signs are often found* on the ancient Egyptian monuments, probably employed by the priests to record dates. The author had occasion to witness this most interesting application of astronomy, in ascertaining the date of a papyrus sent from Egyyt. * * The manuscript was found in a mummy case; it proved to be a horoscope of the age of Ptolemy, and its date was determined from the configuration of the heavens at the time of its construction."—*Mrs. Somerville, p.* 104.

PROBLEM P.

CELESTIAL GLOBE.

To find the time elapsed since the recorded heliacal, acronychal, or cosmical rising or setting of certain stars.

RULE.—Rectify the globe for the given latitude, and note down particularly, the latitude of the star; then,

1. For the recorded cosmical rising:—

Bring that degree of the ecliptic which is the sun's place for the given day to the eastern horizon, and, with a soft pen, make a very small dot exactly on that part of the globe which is of the star's latitude, and is also rising. The degrees of difference between the longitude of this mark and the present longitude of the star, being multiplied by seventy-two, will shew the years required, nearly.

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* There are some of these interesting references to be seen in the British Museum; for instance, that on the interior of the lid of the very ancient mummy coffin in case Q; and that in the interior of the coffin lid in case BBB.

2. For the cosmical setting:—

Make a dot, as before, on that part of the globe which is in the star's latitude and which, whilst the sun's place is rising, is coinciding with the western horizon; then find the difference of longitude of this spot and the star's, and multiply by seventy-two.

3. For the heliacal rising:—

Attach the quadrant to the declination in the zenith, and bring the sun's place for the given day to coincide with the twelfth degree, &c., below the eastern horizon: place a dot on that point in the star's latitude which is rising, and proceed as before.

For the acronychal rising and setting, the sun's place must be brought (as in the former problem) to the western horizon; for the heliacal setting, to the twelfth degree, &c. below it; then the difference between the longitude of the given star and that point on the globe which, being of the star's latitude, is also setting, &c., will shew the time as before.

⁂ It must be explained, in caution, that as precession does not *move* the stars, but only alters the positions of the equinoctial and its pole with regard to them, the point marked by the ink dot is only that position, relative to the equinoctial and its pole, which a star of the latitude of the given one must have had in order to rise as recorded in the question; ***that is, it is the position the given star must have occupied on a celestial globe, if there had been one correctly mapped and mounted so many ages since.***

Ex. 1. The age of Hesiod (the Greek poet) has been the subject of dispute; but he lived in Bœotia (about lat.

38 N.), and he has left it on record that, in his day, Arcturus there rose acronychally sixty days after the winter solstice (about our 19th of February). It is required from this, to ascertain (approximately) the time at which he, and consequently Homer, probably his cotemporary, flourished.

Here, having noted that the latitude of Arcturus is 31°, and having elevated the pole to the latitude of the place, I bring the first degree of ♓ to coincide with the western horizon; and I find that the point in the same latitude as Arcturus which is then rising, is just between the hind leg of the Bear, and the fore-feet of Canes Venatici. I mark exactly this point with a small dot of ink, and find that its longitude differs from the present longitude of Arcturus, about thirty-nine degrees; then multiplying these degrees by seventy-two, I get 2808 years, or 967 years B.C.

Ex. 2. If Thales determined the cosmical setting of the chief star of the Pleiades at Miletus, ($37\frac{1}{2}$° N.) to be twenty-five days after the autumnal equinox, how many years since must he have flourished (nearly)?

The ancients imagined that the heliacal rising of Sirius occasioned the sultriness and distempers of the season at which it occurred; they accordingly named the twenty days preceding and following* the first morning appearance of that star "*dies caniculares*," or dog-days.

Ex. 3. Supposing the middle (15th) of July to have been the hottest part of the year in lat. 31° N., how long is it since, in that latitude, the heliacal rising of Sirius was remarkable as taking place at that time?

The term "dog-days," used in our almanacs to designate the forty days intervening between the 3d of July and the 11th of August, although derived from the calendars of the ancients, and, not many years ago, even accommodated to the changing period of the heliacal rising of Sirius, has now no reference to that rising, but marks only that part of our season in general most sultry. Before the change was made, the precession of the equinoxes had already carried the term considerably beyond the hottest time of year.

Ex. 4. How long must it be before Sirius can rise heliacally in lat $51\frac{1}{2}$° N., amidst the cold fogs or frosts of the 5th of November?

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* Dr. Hutton's Math. Dict. *Art. Canicular.*

The "savans" who accompanied Napoleon into Egypt discovered, on the ceiling of a temple at Denderah, (a ruined town near the ancient Thebes,) an allegorical representation, which they conceived to be a zodiac. The infidels in France were gratified in fancying that they had proved, from the relative position of the solstitial signs in this "zodiac,"* that it recorded astronomical observations of a date far more ancient than the scriptural account of the deluge. But Mons. Champollion,† and others of great eminence, discard the idea of the figures having been intended for a zodiac, or that the temple is of older date than the Ptolemies, or even than the Roman empire. Others, eminently scientific, have imagined that the heliacal‡ or cosmical rising of Sirius may be alluded to in this sculpturing :—for instance,

Ex. 5. In the "zodiac" of Denderah, the figure which has been conceived to represent *Cancer*, is thrown on one side of the line of the signs, and its place is filled by a head of Isis § partly plunged in the rays of the sun :—

Mons. Biot† imagines that this indicates a period at which Sirius rose with the stars of Cancer, near which the sun was on the day of the summer solstice. If this conjecture be the correct one, and the star δ of Cancer (about the middle of the constellation) had then longitude 3 signs 5°, (or 5° ♋,) and the sun was with this star when Sirius rose cosmically, to what distance of time may the sculpture refer ; the latitude of Denderah (anc. Tentyra) being 26° N. ?

Here we make use of 3 signs 5° as the sun's place, and mark a dot in the latitude of Sirius, as directed in the first part of the Rule.

⁂ *It may be interesting to refer to a chronological table, for the events which were transpiring in Egypt about the time thus found.*

Ex. 6. Mons. Fourrier† conjectures that the position of the head of Isis and the displacement of Cancer, referred to above, relate, not to the cosmical, but to the heliacal rising of Sirius ;—Supposing this to have taken place when the star δ of Cancer was coinciding with the sun in 3 signs 5°, what period is referred to?

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* A "zodiac" from Denderah is now in the *Bibliothèque du Roi, Paris.*

† History of Astronomy, Library of Useful Knowledge, p. 16.

‡ The heliacal rising of Sirius was especially noted by the Egyptians, as coinciding with the greatest augmentation of the Nile, the means of fertility to their country.

§ The Egyptians called Sirius, *Isis-Sothis.*

⁂ *Reference may be made, as before, to a chronological table.*

PROBLEM Q.

CELESTIAL GLOBE.

When the time at which an author lived is known, his statement respecting the rising or setting of a certain star may be examined, by making a dot in the latitude of the star, in longitude just so many degrees less than the star now has, as seventy-two years are contained in the time elapsed; and then ascertaining the time of year at which the point so marked now rises or sets cosmically, &c., in the latitude in which the writer lived.

"His (Ovid's) astronomical knowledge was probably derived from the ordinary calendars (see Y, p. 357); and as they were not strictly correct, and the poet, in all probability, did not apply himself with much relish to them, * * * * we are not to look in him for extreme accuracy on this head, and must not be surprised to meet even gross blunders."—*Introduction to Ovid's Fasti (Keightley).*

Ovid, A.D. 10.—*Rome, lat.* 42.—*Alexandria, lat.* 31.

Ex. 1. In the first book of Ovid's Fasti, (line 315,) it is stated that Lyra rose on that day of the Roman year which answers to our 5th of January. Could this have been the case in Ovid's time? How near was the day he has given for the heliac or cosmic rising of this star, to the time of its heliacal setting at Rome;—and how near to the time of its heliacal setting at Alexandria?

Here, making a dot in the latitude of Lyra (Vega), but in longitude

25½° less (since such must have been the relative position of that star in Ovid's time), I find that, with the pole elevated for the latitude of Rome, it could not have risen either heliacally, cosmically, or acronychally, near the time of year given. Then, bringing this dot or relative position of the star to the west, I find that the time of year mentioned as that of its rising, was not far from that of its heliacal setting. But when the pole is elevated for the latitude of Alexandria, it accords with the time of its heliacal setting there very nearly indeed. May it not be inferred from this, that the poet, in this instance, quoted carelessly from a calendar constructed by some mathematician of the famous school of Alexandria about his time?

Ex. 2. In Ovid's Fasti (B. i. line 653) it is stated that Lyra sets on 23rd January:—how does this accord with what then was the heliacal setting of Vega at Rome; and how does it accord with its acronychal setting at Alexandria?

Ex. 3. In Ovid's Fasti (B. v. line 415) it is said that Lyra rose acronychally on 5th May:—how does this agree with what then was the acronychal rising at Rome; and how does it agree with that at Alexandria?

Ex. 4. The following note is extracted from Keightley's edition of Ovid's Fasti (on line 113 of B. v.):—

> "On the Kalends of May," (our 1st May) "the star named *Capella* rises (qy. *rose*) heliacally, according to Neapolis, cosmically, according to Taubner. Is it not acronychally according to Ovid? Pliny makes it take place viii. Id. Maias," (our 8th May.)

None of these will answer for the latitude of Rome and Ovid's time; but if Ovid quoted from a Calendar which, as stated (Y, page 357,) was obtained from the Greeks; and if the computation of that calendar had been for a time somewhat near that of Ovid, but for latitude 31° (that of the school of Alexandria), which of the risings might Ovid have intended?

Ex. 5. [Fasti, B. iii. line 405.] It is mentioned that "Arctophylax" (*Arcturus*) set on the day of the Roman Calendar answering to our 5th March:—could this have been either the heliacal, acronychal, or cosmical *setting* of Arcturus at Rome in Ovid's time?

Ex. 6. State what is the acronychal rising of Arcturus at Rome now; and how nearly its acronychal *rising* at Rome, in Ovid's time, accorded with the time which he inadvertently quotes as that of its *setting*?

Ex. 7. At line 904 of the 4th Book of the Fasti, it is stated that "*Canis*" (the Dog-star) rose on the day that answers to our 25th April:—was this the fact, and on what day did that very brilliant star then set heliacally at Rome?

Ex. 8. Dr. Lempriere says, "Pliny records that *Arcturus* rose in his age on the 12th, or, according to Columella, on the 5th September:"—Supposing this to refer to the cosmical rising of the star, A. D. 60, one of these statements appears to have been correct for the latitude of Alexandria, and the other for that of Rome:—which statement refers to the latitude of Alexandria, and at what time does Arcturus rise cosmically at Rome now?

Ex. 9. Thucydides records that, in the second year of the Peloponnesian war (430 B.C.), Platæa (lat. 38) was invested by the Lacedæmonians about the time of the heliacal rising of Arcturus:—At what time of year must this have been; and at what time of year is the heliacal rising of Arcturus, in that latitude, now?

TROPICAL AND CIVIL YEARS.—YEAR OF CONFUSION.—JULIAN YEAR.—OLD AND NEW STYLE.

The Solar Year,* or period between equinox and equinox, solstice and solstice, is also appropriately called the Tropical Year. Its obviousness, as a cycle of the seasons, has caused it to be adopted, with greater or less exactness, by every civilized nation.

B The Egyptians not only early reckoned by the period of 365 days, but they also soon became aware of the deficiency of this period; for as they reckoned from the heliacal rising of SOTH (Sirius or Canicula,) their months or other subdivisions of 365 days fell forward a whole day every four years; and, in 365¼ times four years, or 1461 years, any of their *dates* thus became attached, in its turn, to the whole round of seasons. This cycle of 1461 years, they named their *Sothiac* period.

C The Roman calendar, in which that in present use by us had its origin, at first consisted of only ten months:—*Septem*ber, *Octo*ber, *Novem*ber, *Decem*ber, still retain the evidence of their places as the 7th, 8th, 9th, and 10th, in that arrangement. *Quintilis* and *Sextilis*, as the *fifth* and *sixth*, were the ancient names of our July and August. Numa Pompilius prefixed January and February, or two moons more, to this vague period; and thus Martius, the first month, became the third one, and the Roman year, containing 355 days, very nearly corresponded with the lunar year.

A civil year, so different in its length from the tropical year, or year of seasons, was the source of great confusion; for it is plain that its commencement would at one time occur in the winter, and at another in the spring, or summer, or autumn.

D "The care of intercalating† lay with the pontiffs, and they lengthened and shortened the year at their pleasure, in order to serve or injure the consuls and farmers of the revenue, according as they were hostile or friendly toward them."*

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* See Q, p. 355.

† *i. e.*, adding or suppressing days to accommodate them to dates.

E In the time of Julius Cæsar, who employed Sosigenes, an astronomer of Alexandria, to rectify the calendar, the civil year was so in arrear of the true or astronomical one, that it was found necessary to decree that the current year should consist of 445 days.—The year 46 B.C., from this circumstance, obtained the name of "the Year of Confusion."

But the length of the tropical or equinoctial year had not then been accurately ascertained. For the purpose of making the solar period and the civil one keep pace with each other, Sosigenes introduced one day every four years, by arranging that the 6th (*sextilis*) of the calends of March† and the following day, should be considered but one day. But this correction is in excess, for the tropical year being 365 days, 5 hours, 48 minutes, 49$\frac{7}{10}$ seconds, instead of 365 days, 6 hours, an error arises of 11 minutes, 10$\frac{3}{10}$ seconds per annum, which in 900 years amounts to seven days.

F The festivals and fast days established by the Nicene Council in the year 325, referred to Easter as connected with the vernal equinox. In the age of Pope Gregory XIII., the excess in the Julian compensation of six hours per annum, had carried dates back ten days:—the equinox was found to be occurring on the 10th instead of on the 21st of March, and the celebrations of the Romish church were found to be in danger of changing their seasons.

To remedy this, the Pope ordered the suppression of ten nominal days—the day succeeding the 4th of October, 1582, being called the 15th day; and thus two "styles" or reckonings were introduced, for the Protestants of Europe withstood the innovation.

G It was not until 170 years after this, (and the loss of another day by the Julian mode of reckoning,) that the Gregorian year, or change of "style," was adopted in England. In A.D. 1752, by act of Parliament, the 3d of September was called the 14th:—eleven nominal days being thus omitted, to bring forward the dates. In order to prevent the future accumulation of error, it is arranged in the Gregorian calendar, that the last February of every century not divisible by four, shall be deprived of the intercalary day :—thus, the February of A.D. "*eighteen* hundred" consisted of 28 days only : this will be the case with the February of "*nineteen* hundred," but not with that of A.D. "*twenty* hundred." By this means the error would not amount to a whole day in several thousand years.

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* Keightley's *Ovid's Fasti*.

† Hence the term "*Bissextile*." We introduce the additional day at the end of February, because of the shortness of that month.

[H] Before A.D. 1752, the Civil year of England began on the 25th of March :—the year 1751 had but three "quarters," for it was enacted that 1752 should begin with the 1st of January, in accordance with the Roman computation. Whilst the two "styles" existed in Europe, it was usual to write a date intervening between the 1st of January and the 25th of March with reference to both styles,—thus February 3, 172$\frac{8}{9}$, *i. e.*, 1728 of the old style, or 1729 of the new one.

Russia still adheres to the old style, and there is thus a difference of 12 days between Russian dates and those of the rest of Europe.

PROBLEM R.

FOR SUNSHINE.

Let a table, or piece of broad plank (as a drawing-board) be placed strictly horizontal in the sunshine; and, by means of a mariner's compass, let a chalk line be marked upon it exactly north and south.

Let the terrestrial globe be now placed upon this table or board, with its meridian coinciding with the chalk-line: —let its pole be elevated to the latitude, and the place of residence brought to the brass meridian and thus placed uppermost: then,

1. Since the distance from the surface of the earth to its centre is insignificant when compared with the distance of the sun, his beams will be spread over the latitudes and longitudes depicted on the globe exactly as they would be were its centre where the earth's centre is; or as they are, at that instant, spread over the latitudes and longitudes of the earth's surface.

Thus we may see, notwithstanding the interfering shadows of the brass meridian and wooden stand of the globe, many of those places which are situated at the terminator or boundary of sunlight, and which, consequently, are having a rising or setting sun at that time.

2. The extent to which the sunbeams reach over one of the poles will shew the sun's declination; and, if the globe be caused to rotate, it will be seen, by examining the two frigid zones, which places are having their periods of continuous light and which are having continuous darkness.

Thus, if we make the experiment on the 25th April or 18th August, it will be seen that the sun is shining $13\frac{1}{4}°$ over the North Pole; and that, during the rotation of the globe, all places nearer than this to the North Pole, or having more north latitude than $76\frac{3}{4}°$, cannot lose his beams; whilst those that have more than $76\frac{3}{4}°$ of south latitude cannot receive them.

3. If a long fine needle be one-half dipped into thick gum or strong varnish, and by this means stuck to the graduation of the brass meridian exactly *along* the mark which

is generally made larger than the rest to distinguish the 90th degree, or Pole, the shadow of this needle will shew the longitude in which the sun is vertical at the time; for *it will be cast upon*[*] *the opposite semicircle of the plane of the meridian of that place*; and every semicircle has for its longitude the supplement [†] of the opposite one: In other words, the longitude of the place which then has a vertical sun, and of all others that are having noon, is just equal to the degrees of distance at which the needle-shadow falls from the under semicircle of the brass meridian.

Thus, suppose we were making this experiment at Greenwich at 22m. [‡] before 7 in the morning of 25th April or 18th August;—if we search for the longitude of the spot upon which the shadow of the extremity of the needle falls, we shall find it to be 99½ west; and subtracting this from 180, we shall get 80½ for the east meridian on which the sun then is, or where it is noon.

⁂ If the globe have that very inconvenient appendage, an hour-circle *outside* the brass meridian, a small cone of wood (very easily formed with a penknife) might, for the time, be fitted and glued on to the extremity of the axis or pivot of the index.

4. If a fine needle be now stuck perpendicularly into the globe at that spot which has latitude equal to the sun's declination, and longitude such as that just found by means of the shadow, and the place of residence be again brought to the brass meridian, it will be seen that the sun is vertical to that spot, for the needle will cast no shadow.

Thus if, as before supposed, we were attending to this at 22 min. to 7 A.M., on 25th April or 18th August, we should find that (the sun having 13¼° of north dec.), the place having longitude 80½ east and the sun in the zenith, must be *Madras*.

⁂ To ensure the perpendicular insertion of the needle, it is well to bring the place so found to the brass meridian and to be guided by the graduation in inserting it. Very fine needles may be so stuck into the globe as not to injure it.

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[*] If, when the place of residence is coinciding with the brass meridian, the hour circle (under the meridian) be set to 12, the shadow cast by the needle will likewise give the *hour*. The shadow of the brass meridian sometimes interferes with this; but, even then, the meridian on which the extremity of the needle-shadow falls may be traced up to the hour corresponding with it.

[†] The supplement of any number of degrees is what it wants of 180.

[‡] We need solar (sun-dial) time for this:—On the two days supposed there is very little difference between the sun-dial and the clock; but the difference for any day may be found in the little table of the equation of time given a few pages onward.

5. If we measure 45° around this spot by means of the quadrant (or a piece of white thread marked with that length), and stick fine needles perpendicularly into several places so situated; then, whilst the needle stuck into the place having the sun vertical casts no shadow, each of these others will cast a shadow exactly equal to its length; for the sun, at each of the places represented by those spots, is 45° from the zenith, and therefore 45° high. (X, on p. 13.)

Thus *Tobolsk*—*Pekin* (nearly)—the *S. E. part of Celebes*—*Cape St. Andrew* (Madagascar)—*Jerusalem*—*Damascus*—*the eastern shore of the Black Sea*, &c., are all 45° distant from Madras; and needles inserted perpendicularly into the globe-surface at these places, will, at this time, cast shadows equal to their lengths; but all of course differing in their direction, and shewing, so far, the opposite bearings of the sun at those several places.

6. If a needle be stuck into each of the temperate zones,—one at a spot due north, and the other at a spot due south, of the place having the sun vertical; and a third needle in the enlightened frigid zone;—it will be seen that, whilst the inhabitants of the temperate zones are Heteroscii (def. 74), and those having a vertical sun are Ascii (def. 73),—the inhabitants of the frigid zone are Periscii (def. 75), because, as the globe rotates, their shadow falls in every possible direction with regard to the North Pole.

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7. If the globe could be placed even where the moon is at the time (provided that the plane on which it stood were, like that on which it now stands, parallel to our horizon, and its meridian, as now, were due north and south), then the several circumstances already mentioned—the bearings and lengths of shadows, &c.—would differ in no perceptible degree from those shewn on the globe here; for the separation of the moon from the earth being only about one-four-hundredth of the distance of either from the sun, he may be regarded as shining on both as if they were *together*.

DIALLING.

THE HORIZONTAL DIAL.—THE VERTICAL DIAL.

K We have just seen (*note*, p. 377)* that when our terrestrial globe is arranged in the sunshine, with due regard to its horizon and the plane of the meridian, the needle,† which is but a prolongation of the axis, will cast its shadow on the opposite semi-meridian to that on which the sun is shining, and that it may thus be used to mark solar time, if we refer its shadow upward to the horary circle or index when the *twelves* of that circle are coinciding with the brass meridian, or our own plane.

It will be equally easy to see, that, however long the needle may be, provided it be straight and well adjusted to the axis, its shadow will fall *along* the meridian opposite to the sun; and thus, if it were long enough, its shadow would even fall upon the horizon of the globe, exactly where the shadowed semi-circle meets that wooden circle. Hence, if we were to mark the wooden horizon where it is cut by the several meridians, with the hours, &c., to which those meridians correspond, the prolonged shadow of the needle would shew us the time on that also.

The common horizontal sun-dial is a construction upon this principle:—

L The whole axis of the earth, or globe, is in the plane of every meridian (G *and its note*, p. 9), and therefore, if we suppose the terrestrial globe, with all its meridians, to be removed from its frame, and its axis only to be left, (*inclined* as before, *to the latitude*,) the shadow cast by the axis will be identical with the shadow of any meridian that the sun may be shining opposite to, and will as faithfully shew the time on our horizon, so marked as we have supposed.

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* If there have been no opportunity for performing Problem R in the sunshine, it must at least be read over very carefully before attending to what follows here.

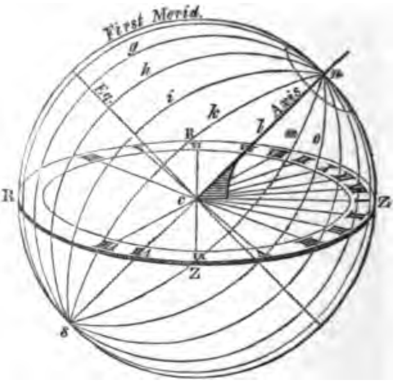
* See *n* in the figure on the next page.

By rectifying the globe for several latitudes, the pupil will perceive,

1. That each different elevation of the pole causes a difference in the points at which the meridians, or their shadows, intersect the horizon:—

Thus, with an elevation of the pole for 24° or 30° it will be seen, that on a dial constructed for so low a latitude the hour-arcs nearer to the north point (or XII) will be very small, and those nearer to VI, or the east and west points, will be much greater; whereas, with an elevation of the pole for 60°, or even for our own latitude (51½°), those hour-arcs are more nearly equal.

2. And hence, that the "Gnomon" or "stile" of a horizontal sun-dial must be placed in position with the axis of the earth, by being set in the plane of the meridian with an inclination according with the latitude, or it will not shew the time upon the face of the dial, however correctly the face may be marked.



Let the adjoining figure represent a transparent globe with the usual meridian lines marked upon it. Let *c* be its centre, and *n c* that half of its axis which is above (or northward) of R Z Z R, the plane of the rational horizon:—

Then *n* may represent the needle we have supposed to be attached to the north pole (3 on p. 376)—*k*, *l*, *m*, *o*, &c., meridians of the eastern hemisphere,—and I, II, III, IIII, V, VI, &c., the points at which they intersect the horizon, when the pole is elevated for lat. 51½°,—the numbers IIII, V, VI, VII, VIII. &c., (seen through the globe,) marking the points of similar intersection of the western horizon, by the semi-meridians opposite.

It is evident that when the sun is "on" the "*first meridian*," or due south, the shadow of the axis, or of the opposite semi-circle, will be cast on XII, or the due north of the horizon; but that when the sun is yet only on *g*, (15° eastward, or an hour earlier,) this shadow of the axis, or of the opposite semi-circle, will fall on XI; when he is only on *h*, (and giving noon in 30° east longitude,) this shadow will fall on X, &c., &c.

COMPARED WITH A WELL-REGULATED CLOCK, ON THE DAYS GIVEN BELOW, THE SUN-DIAL IS

SLOW.		FAST.		SLOW.		FAST.	
Dec. 25	0 min.	Apr. 15	0 min.	June 16	0 min.	Sept. 1	0 min.
26	1 ,,	19	1 ,,	20	1 ,,	3	1 ,,
28	2 ,,	24	2 ,,	25	2 ,,	6	2 ,,
30	3 ,,	30	3 ,,	29	3 ,,	9	3 ,,
Jan. 1	4 ,,	May 13	4 ,,	July 5	4 ,,	12	4 ,,
3	5 ,,	29	3 ,,	11	5 ,,	15	5 ,,
5	6 ,,	June 5	2 ,,	28	6 ,,	18	6 ,,
7	7 ,,	10	1 ,,	Aug. 9	5 ,,	21	7 ,,
9	8 ,,			15	4 ,,	24	8 ,,
12	9 ,,			20	3 ,,	27	9 ,,
15	10 ,,			24	2 ,,	30	10 ,,
18	11 ,,			28	1 ,,	Oct. 3	11 ,,
21	12 ,,					6	12 ,,
25	13 ,,					10	13 ,,
31	14 ,,					14	14 ,,
*Feb. 10	15 min.					19	15 ,,
21	14 ,,					* 27	16 min.
27	13 ,,					Nov. 15	15 ,,
Mar. 4	12 ,,					20	14 ,,
8	11 ,,					24	13 ,,
12	10 ,,					27	12 ,,
15	9 ,,					30	11 ,,
19	8 ,,					Dec. 2	10 ,,
22	7 ,,					5	9 ,,
25	6 ,,					7	8 ,,
28	5 ,,					9	7 ,,
Apr. 1	4 ,,					11	6 ,,
4	3 ,,					13	5 ,,
7	2 ,,					16	4 ,,
11	1 ,,					18	3 ,,
						20	2 ,,
						22	1 ,,

The dates commencing the columns are those on which the sun-dial and clock agree, as mentioned in note to definition 87. The two days on which the equation of time is the greatest are marked with an asterisk.

The equation of time is marked, in very small figures, against the days on the wooden circle of Bardin's Globes, the marks + and — (plus and minus), denoting whether the clock is faster or slower than the sun-dial.

PROBLEM S.

TERRESTRIAL GLOBE.

To find the hour-arcs, or angular distances of the hour-lines, for a horizontal dial, the latitude being given.

1. *If the meridians be drawn on the globe through every 15°, as they generally are:—*

Rule.—Elevate the pole for the given latitude, and bring the first meridian (or any other) to the brazen meridian; then note down the distances from the under semi-circle of the brass meridian, at which the horizon is intersected by the several meridians, taking so many only as there are hours in the half of the longest day. Thus in a horizontal dial for north latitude, the north point being XII, or noon, the points of intersection towards the east, and beyond it, will be the places of the afternoon hours, I, II, III, IV, &c.; and those at corresponding distances from the north towards the west* and beyond it, will be the places of the morning hours, XI, X, IX, VIII, &c. (See the figure.)

The places of the half-hours may be marked by turning the globe 7½°, and noting again the intersections of the several meridians; and the places of the quarter-hours, by turning the globe 3¾°;—but this will require that the globe be in excellent condition.

2. *If the meridians of the globe be drawn, as they sometimes inconveniently are, through every 10°:—*

It is evident that, in this case, the intersections of the meridian lines will be at every forty minutes, instead of being at every sixty minutes; that is, the arcs from N. to E., instead of being for I, II, III, &c., will be, respectively, those for forty minutes past XII,—twenty minutes past I,

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* The intersections from north towards west, and beyond it, being at the same angular distances as those from north towards east, and beyond it, they need to be found only for one side.

—II,—forty minutes past II,—twenty minutes past III,—IV, &c.; hence,

Rule.—Having marked off the intersections which shew the places of the even hours II, IV, VI, VIII, &c., turn the globe 5° westward, and the intervening intersections will be at the odd hours, I, III, V, &c., which may be noted accordingly.

The places of the half-hours, &c., may be found as before.

Ex. 1. What are the arcs between the hours XII and I, or XII and XI,—and XII and II, or XII and X, on the face of a horizontal sun-dial for Belfast, lat. 54½° north?

Here, elevating the pole 54½°, I find, that when a meridian line is brought to coincide* with the brass meridian, the two intersections first on each side of the north point (or XII) on the horizon, (and which are the places of the hours XI and I,) are each at an angular distance of 12⅓°,—the second, on each side of the north point, (or the places of X and II,) are at 25⅛°, &c., &c.

Ex. 2. Find the hour-arcs for the remaining parts of a day on the horizontal dial proposed above, the longest day at Belfast being a little more than seventeen hours.

Here it is evident that the utmost *hour*-lines will be those of IV A.M., and VIII P.M.

Ex. 3. Find the angular distances of the hour-lines and half-hour lines of a horizontal dial constructed for London or Blackheath.

Ex. 4. Describe a horizontal dial for the latitude of Petersburgh, or the south of Mainland, Shetland.

Ex. 5. What difference is there between the angle contained by the hour-lines of I and II, or XI and X, on a horizontal dial, constructed for Petersburgh, and the angle contained by those hour-lines on one constructed for the Bermudas?

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* It will be found convenient to keep it coinciding by the under semi-circle.

Ex. 6. What difference of degrees on the same two dials, between the numbers VI and VII?

Ex. 7. Describe horizontal dials for Lisbon and Washington.

Conversely.

Ex. 8. For what latitude must that horizontal dial have been made, on which the hours of IV and V are separated 20°?

Ex. 9. Where might a horizontal dial be erected, which would shew correct time by the motion of the shadow of its stile or gnomon over 15° each hour, or one quarter of a degree each minute; and what inclination must its gnomon have?

A sun-dial the face of which is perpendicular to the horizon, and therefore in the plane of the zenith and nadir, is called a vertical dial. It is a convenient one, and is often placed against the south wall of a church; but as the sun, at no time of the year, shines upon a wall so situated longer than twelve hours, the hours from VI to VI are all that are marked upon such a dial.

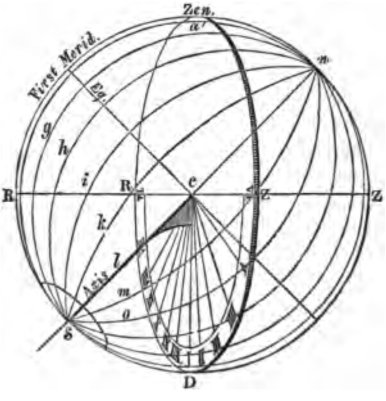
Since the distance of any two places on the earth's surface is insignificant when compared with the sun's distance, it is evident that a dial constructed for the *horizon* of any latitude will shew us the time at our own place of residence, provided that, first taking care to place it duly north and south, we also incline its plane or face to our horizon just so much as the horizon of those who live due north or south of us in that latitude inclines; that is to say, if, according as the latitude for which it has been made lies northward or southward of us, we depress the north or south points of the surface of the dial.

Thus, Mainland of the Shetland Isles lies in latitude 60° N., or 6° due north of the city of York. A horizontal dial constructed for latitude 60°, and consequently adapted to shew correct solar time in Shetland, would serve for that purpose also at York, (notwithstanding the difference of its hour-arcs and of the inclination of its stile,

if, after being adjusted to the meridian, the XII or north point of its plane were depressed 6°; for the distance of York from Shetland, or any other place, is insignificant; and the dial being thus arranged, the sun may be considered as shining on it *in* Shetland.

The mouth of the Ebro has, very nearly, the longitude of Blackheath, and the latitude of Madrid, or 40½° N.—A horizontal dial for that latitude would shew solar time at Blackheath, as well as at the mouth of the Ebro, if, after setting it north and south, we were to incline its plane 11° southward; for its gnomon would thus be brought parallel to the earth's axis, and its surface would be in position with an horizon for which it was made.

N The south point of the vertical dial used in north latitudes is, of course, depressed 90°; and thus it appears that such a dial, in use by any of us, is the horizontal dial of those who dwell 90° south of us, or just so far south of the equator as we are south of the pole. Hence, it is the southern half of the axis that is represented by the gnomon of such a dial, and the inclination of its gnomon is always equal to the complement of the latitude in which it is fixed up.



Let the adjoining cut represent, as before, a transparent globe, with its meridians; let *c* be its centre, and R, Z, Z, R, an horizon of lat. 51½° N.

Then *Zen*, Z, D, R, will represent a plane vertical to this horizon, and *S*, *c*, the *southern* half of the axis depressed 51½° below R, Z, Z, R; and therefore making an angle with the vertical plane equal to the complement of 51½°, or 38½°.

It may be seen, by turning the figure so as to bring D to the left, that this would be a horizontal dial in lat 38½° S.

⁂ In like manner, if we turn our page 380, so that its *n*, or *needle* end of the axis, may be directed downward on our right hand, it will be perceived that our horizontal dial would serve for the vertical one of lat. 38½° S.

PROBLEM T.

TERRESTRIAL GLOBE.

To find the hour-arcs of a vertical dial facing the south in north latitude, or facing the north in south latitude, the latitude being given.

RULE.—Find the complement of the latitude, and elevate the pole of contrary name. Bring the first meridian (or any other) to coincide with the brass meridian; then taking the point at which the under semi-circle of the brass meridian intersects the wooden circle of the globe for the place of the shadow at XII or noon,—note down the points of intersection of the wooden circle by the meridians towards the *east*, for the afternoon hours I, II, III, IV, V, VI, and the points of intersection of those towards the *west*, for the morning hours XI, X, IX, VIII, VII, VI.

For half-hours, &c., the globe may afterwards be turned 7½° &c., as directed in Problem S.

If the meridians of the globe be drawn through every 10°, instead of through every 15°, the even hours II, IV, &c., must first be marked, and the odd ones, after turning the globe 5° westward, as directed in the second part of the rule for Problem S.

Ex. 1. Find the hour-arcs of a vertical dial facing the south at Belfast, lat. 54½° N.

Here, elevating the south pole to the difference between 54½° and 90°, or 35½°, I find that, when any meridian is brought to coincide with the brass meridian—of the five meridians intersecting the wooden plane between the points marked "south" and "east," the first, or

place of the shadow at 1 P.M., intersects at an angular distance from the south point of very nearly 9°,—the second, or shadow's place at II, intersects at 18½°, &c. &c.; the intersections between the south and west points (and which are the places of the shadow at XI, X, &c.), being at the same angular distances.

Ex. 2. Furnish the remaining hour-arcs on the abovementioned dial.

Ex. 3. What are the angular distances at which I must draw the lines on a dial intended to be fixed up against the south wall of a church in London?

Ex. 4. Find the hour-arcs of a vertical dial, facing the south, in Lisbon, and state where this might be used as a horizontal dial (N, p. 385).

Ex. 5. What must be the hour-arcs on a vertical dial, facing the north, placed against a wall in the middle of New Zealand, lat. 38½° south?

Ex. 6. Suppose vertical dials facing the north to be required for parts of Chili and New Zealand, in lat. 35½° S.,—from which north part of the world might they be supplied without the trouble of manufacturing new ones?

Ex. 7. With the inhabitants of what remarkable places might Edinburgh exchange horizontal dials for vertical ones?

Ex. 8. Having graduated 24 hours on the whole circumference of a disk of card-board, on both sides, and set it horizontally, I have also inserted a straight pencil half-way through its centre, with care to keep it perpendicular to this plane or disk:—

If I now raise the south point of this plane to the complement of my latitude, so as to direct it to the equinoctial in the heavens, to what two points in the heavens will the ends of the pencil be directed—with what great circle of the earth will the disk be parallel—for what two places diametrically opposite to each other will the surfaces of the card be horizontal dials—why will such a disk shew me *my* solar time—and on which side of it will shadows be cast during my winter hours?

PROBLEM Z.

CELESTIAL GLOBE.

To map down a group of constellations, having a certain star given as central.

Rule.—1. Bring the given star to the brass meridian, and elevate the pole to its declination:—attach the quadrant of altitude over the star, and (by Prob. X. p. 87) make out a list of the stars around it with their degrees of distance from this central star, and with the several bearings they have from it whilst it is thus in the zenith.

2. Having described a circle of convenient size on a piece of card-board or stiff paper, and drawn diameters at right angles, mark the uppermost point N.—the undermost S.—the *right*-hand point W.—and the left-hand point E.;—the degrees of each quadrant being set off *from* N. or S. *toward* W. or E. by a protractor.*

3. At the centre of this circle mark the Greek letter and number expressing the magnitude of the star used for the central one of the group; and then, by means of the graduated edge of the quadrant of altitude, set off pencil dots at the degrees of distance and several bearings registered in the list just made; marking each of such dots (as soon as made) with the Greek letter and magnitude of the star it represents.

4. If the places of these dots be now carefully pierced with pins of different thicknesses, the card or paper will be of considerable assistance in tracing the constellations

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* When we have not a *protractor* at hand, the degrees of a circumference may be set off from the equator of the globe, if we draw it with the semi-diameter of the globe; or, if this be too large for the paper, each half degree of the globe will be a degree on a circumference drawn with *half* its semi-diameter:—thus, for instance, if we draw a circle with the compasses open three inches, we may use for degrees the half-degrees of a twelve-inch globe.

in the heavens ; * especially if the outlines of the figures to which the stars of the group belong, be lightly traced with a pen dipped in oil or varnish, to render them partially transparent.

Ex. 1. Taking γ of Ursa Major as a centre, map down the stars in *Ursa Major* and *Ursa Minor*.†

α 1	distance from γ	—°	bearing from γ	—°	N. to W.
β 2	,,	—°	,,	—°	do.
δ 3	,,	—°	,,	—°	N. to E.
ε 3	,,	—°	,,	—°	do.
	&c.	&c.	&c.	&c.	

Ex. 2. Taking δ of Orion as the central star, map down the stars in *Orion*,—*Lepus*,—head and horns of *Taurus*,—*Canis Major*,—*Canis Minor*,—and heads of *Gemini*.

Ex. 3. Taking β of Cygnus as central, draw, and prick out, the group containing *Cygnus*, *Lyra*, *Aquila*, and *Delphinus*.

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* The constellations beyond the bounds of the card, and even those *below* the horizon, may be *imagined* and readily pointed towards by the aid of the "*Rhymes on the Constellations*," given in the *Appendix*.

† The author is aware that such a 'mapping' will be distorted ; but the advantage will, nevertheless, be considerable.

ASTROLOGY.

P The terms astronomy (αστρονομια) and astrology (αστρολογια) were synonymous amongst the Greeks, and Cicero uses the word *astrologia* in a similar manner.

But "judicial astrology," a pretended science, was very generally received among the nations of antiquity (except the Greeks), and was also much cultivated in Europe during the middle ages. The basis of this science was the supposition that the heavenly bodies affected the destinies of mankind.

A knowledge of the terms and principles of this pretended art is desirable as furnishing a key to expressions made use of by several authors.

Q The apparent hemisphere of the sky was divided into *six* portions, by imaginary lines, like the meridional semicircles of the common globe, but originating in the north point of the horizon of any place and terminating in its southern point. The hemisphere below, and invisible, being divided in similar manner, the *twelve* divisions were called "houses of heaven." The principal points attended to in each 'house' were—the part of the Zodiac which occupied it at any instant as the heavens revolved from east to west through these twelve stationary 'houses,' and—the place of any planet which, from its position in the Zodiac, might happen to be in a certain 'house' at that certain time.

R "These 'houses' had different 'powers.' The strongest was the first, which contained the part of the heavens about to rise;—this was called the 'ascendant;' and the point of the ecliptic which was just rising was called the 'horoscope.'"

The twelfth was the 'house' just above and along the eastern horizon; and the tenth, which was that from which the heavenly bodies were just culminating, was the next or *second* in 'power.'

S " Each 'house' had one of the planetary bodies as its 'lord,' who was stronger in his own house than any other, as was fit;—and, of two planets equally 'strong' in other respects, he who was in the stronger house was the stronger.

* * * *

" In the fifteenth century Stœffler* foretold a universal deluge which should take place in 1524, in consequence of three planets being then in conjunction in a *watery* sign. All Europe was in consternation, and those who could find the means built boats in readiness. A doctor of Toulouse is said to have made an ark for himself and his friends."—*Penny Cyclopædia.*

[In the same century, Pope Calixtus III. directed prayers and anathemas against a comet, which had either assisted or predicted the success of the Turks against the Christians.]

T Astrologers have disregarded the very important circumstance of the Precession of the Equinoxes (see p. 354), although Aries, Taurus, &c., are now, in consequence of this, a whole sign in advance of their former situations in the ecliptic!

" A number of infamous characters, sometime after their death, are made gods and goddesses:—In a course of years their names (Mercury, Venus, &c.) are arbitrarily imposed on the planets which have existed from the beginning of the world. Then the various attributes, such as stupidity, moroseness, deceit, wantonness, cruelty, and the like, for which these gentry were celebrated, are supposed to be transmitted with their names, and a small portion of some sort of goodness, to the different planets where they then reside; but whether upon them or in them does not exactly appear.

" Then these large dark insensible bodies, with their fine tempers, as they continue their mystic dance round the sun, sometimes near together, then farther off, then opposite to each other; and changing their tempers as they change their places and their partners; occasion, or at least influence, the various vicissitudes of individuals and empires!" *

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* A German mathematician.

"The Chaldæans have been celebrated in all ages for their attachment to judicial astrology; the Chinese from time immemorial have considered solar eclipses, and conjunctions of the planets, as prognostics of importance to the empire, and the observation of them has been a matter of state policy. Traces of a similar belief may be found in Egypt and India; and there can be little doubt that to a superstition vain and degrading in itself, we owe the early observations made in China and Babylon, the zeal with which the Arabs embraced the science of Ptolemy and the revival of astronomy in modern Europe."†—*History of Astronomy, Library of Useful Knowledge.*

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* From "*the Panorama*," the manuscript of a revered friend of the author, the late Rev. J. T. Barker. (Quoted in *Time's Telescope*, by his late son.)

† See A. D. 750 in the chronological table given next.

CHRONOLOGY

OF ANCIENT OBSERVATION AND DISCOVERY.

THE honour of being first in astronomical study has been variously ascribed to the Chaldæans, the Egyptians, the Chinese, and the Indians.

V The term Chaldæan is often used by ancient writers to designate an astronomer; but it is believed that whilst they rested their predictions of eclipses, &c., on the periods ascertained by long observation, the Chaldæans were content to account for celestial phenomena by the most absurd and contradictory notions; and there does not exist any proof that the ancient Egyptians had any knowledge of the true system of the universe.

The extended flatness of the regions first cultivated, as well as the purity and serenity of their atmosphere, was particularly favourable for observation. The observations of many centuries were transmitted by these nations to posterity by engravings on bricks and public monuments. But the Egyptians were indebted to Thales (only 600 B. C.) for the method of finding the height of their Pyramids by the lengths of their shadows.

W Of the astronomy of the Chinese the most contradictory statements are furnished; some historians granting it its claim to an origin in their first emperor *Fohi* (or Noah!), and others yielding to it a derivation only from Greece, through the Arabs and Persia. It is stated that there is an observatory at Pekin supported by public authority. Probably, like the Chaldæans and Egyptians, from a very early and long continued registry of certain astronomical events, they were able to discover periods near to which they would again occur.

Jesuit missionaries were long resident in China, and were even officially employed in scientific pursuits by the Chinese government;

but they were able to collect "nothing beyond detached observations and fragments of science."

X The claims of Indian astronomy have been considered by many to rest on similar grounds; but M. Bailly, who examined and compared four different sets of astronomical tables of the Indian philosophers, found that they evinced a knowledge remarkably correct in regard to some of the more intricate parts of the science.

The observatory at Benares is an interesting monument of Indian science. Japan and Siam also lay claim to an early cultivation of astronomy. One of the sets of tables referred to above was Siamese.

Y It was from the Greeks that astronomy first derived its true scientific character:—The arbitrary grouping of stars into constellations; the division of the Zodiac into twelve signs; a knowledge of *five* planets; and some notion of the nature and motions of comets, were probably received by them from others.

"The later chiefs of the Greek schools followed the earlier masters; and though they varied much, they added little. The Romans adopted the philosophy of their Greek subjects; but they were always, and indeed acknowledged themselves to be, inferior to their teachers."—*Whewell's Inductive Sciences*, vol. i. p. 84.

B. C. 600.—THALES (of Miletus, in Asia Minor) divided the heavens by five circles,—the Equator (Equinoctial), the two Tropics, the Arctic and Antarctic circles; taught the apparent revolution of the sun in 365 days; that night was created* before day; that the stars are fiery bodies; that the moon is an opaque body illuminated by the sun; that the earth is spherical and *placed in the centre of the universe.*†

Thales was the first Greek who predicted an eclipse (probably depending on the Chaldæan periods). M. Bailly computed this eclipse backward (D, p. 307), and found the 10th September, 610 B. C. to have been the day answering to its occurrence, which was memorable as "changing day into night," and terminating a war between the Medes and Lydians.

B. C. 530.—ANAXIMANDER, ANAXIMANES, ANAXAGORAS, were pupils and successors of Thales. Anaximanes invented, or introduced the Gnomon.* He set up a sun-dial at Lacedæmon; observed the obliquity of the Ecliptic; taught that *the sun was not less than the earth;* and is said to have made the first globe. Anaxagoras taught that the moon was habitable, consisting of hills, valleys, and *waters.*

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* *See def.* 104. Thales had resided in Egypt and Phœnicia, and had become acquainted with the Jewish system.

† What was erroneously surmised is printed in Italic.

B. C. 540.—PYTHAGORAS (who, after long and extensive travelling,† settled at Crotona, in the bay of Tarentum (Italy), and founded 'the Italian Sect') was cotemporary with the philosophers last mentioned. He taught that *the universe is composed of four elements;* that it had the sun in the centre; that we had antipodes; that comets were *a kind of wandering stars,* disappearing in the superior parts of their orbits, and becoming visible only in the lower parts of them; that the whiteness of the milky way was occasioned by the brightness of a great number of small stars; that the planet Venus is both the Morning and Evening star.

B. C. 400 to 350.—PHILOLAUS (a Pythagorean of Crotona, who flourished in the century succeeding Pythagoras and was cotemporary with Plato) asserted the annual motion of the earth round the sun.

HICETAS (at Syracuse) taught the earth's diurnal motion on its axis.

METON (at Athens) was the inventor of the "Metonic Cycle." (See F, p. 336.)

PLATO, and his pupil ARISTOTLE, about this time obscured the science of astronomy, by adopting the notion that the earth is at the centre of the universe.

> "It was the radical error of the Greek philosophy to imagine, that the same method which proved so eminently successful in *mathematical,* would be equally so in *physical* enquiries; and that, by setting out from a few simple and almost self-evident notions, or axioms, every thing could be reasoned out."—*Herschel's* "*Discourse,*" p. 108.

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* The Gnomon of the ancients was an upright pillar erected on level ground, in order that, by examining the length of its shadow, the elevation of the sun, &c., might be known. It has been thought by some that the Pyramids of Egypt were originally designed for gnomons. The Spaniards who conquered Peru found, in that country also, pillars of costly workmanship, the shadows of which were used to determine the equinoxes.

† Pythagoras had resided in Babylon during the latter part of the Jewish captivity, and probably had been in intercourse with Daniel and Ezekiel.

"There arose an unwieldy, if not self-contradictory, mass of hypothetical motions of sun, moon, and planets, in circles, and these again in others without end—" cycle on epi-cycle, orb on orb"—till, at length, as observation grew more exact, and fresh epi-cycles were continually added,* the absurdity of so cumbrous a machine became too palpable to be borne."—*Herschel's* "*Discourse,*" p. 266.

B. C. 370.—**Eudoxus** taught (in Asia and Italy) that *the diameter of the sun is nine times* that of the moon. He is said to have determined 365 days 6 hours as the length of the year. (See Q, on p. 354-5.)

B. C. 333.—**Calippus** (of Athens) corrected a slight defect in the Lunar Cycle of Meton, by subtracting one day in four of those periods, or 76 years.

At this time, or a little earlier, the Greeks, in colonizing a portion of Gaul, are said to have become acquainted with the astronomical notions of the Druids.

B. C. 300.—**Autolychus** wrote two books, viz., "Of the Sphere which moves," and "Of the rising and setting of the Stars;" in which he pointed out the phenomena of the *Right, Parallel,* and *Oblique Spheres.* (Def. 49, 50, 51.)

B. C. 300.—**Euclid** (contemporary with Autolychus), flourished in Egypt. Euclid reduced into order all the fundamental principles of pure mathematics which had been delivered by Thales, Pythagoras, Eudoxus, and other mathematicians before him, adding many others of his own discovery. (Euclid was not an astronomical observer.)

B. C. 264. **Aristarchus** (of Samos) taught, that when the moon is *dichotomized,*† we are‡ in the plane of the circle which separates the enlightened and the unenlightened portions. He strenuously advocated the Pythagorean system.

B. C. 230.—**Erastothenes**, assisted by the munificence of Ptolemy Euergetes, placed in the portico of Alexandria certain armillary§ spheres, (afterwards very successfully employed by Hipparchus and Ptolemy the astronomer.) He attempted to ascertain the actual circumference of the earth, by finding the astronomical arc intercepted between the zeniths of two places (See V, pp. 228—9). By observing the distances between the two tropical points in the heavens, he attempted to ascertain the obliquity of the ecliptic. He taught that this obliquity consisted of 23° *fifty-one minutes*. (See def. 62.)

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* *i. e.* to reconcile new observations.

† Cut into two equal and similar parts.

‡ See S, *and its notes* 1 and 2, on p. 301.

§ An armillary sphere is a kind of *skeleton* sphere, consisting of several circumferences of metal put together in positions according with those of the several imaginary circles of the heavens. One of 18 feet diameter, and capable of containing 30 persons sitting within it, was, some years ago, constructed by Dr. Long at Cambridge.

Astronomers recognize a very minute variation in the position of the ecliptic or plane of the earth's orbit, as arising from the disturbing attractions of the rest of the planets, especially of Jupiter. The present mean obliquity of the ecliptic, as given in the Nautical Almanac for 1842, is 23° 27′ 35″ $\frac{61}{100}$:—the amount of its variation is 48″ per century, or nearly one half second per annum. If we allow 16′ for the change during the twenty centuries elapsed since Eratosthenes, his observation differs surprisingly little, considering the inferior means he must have possessed of being correct.

B. C. 227.—Archimedes (of Syracuse), (the Newton of antiquity,—contemporary with Eratosthenes of Alexandria), justly celebrated for the greatness of his genius and the variety of his inventions in mechanics and geometry—was unacquainted with trigonometry properly so called—but is said to have determined the distances of some of the planets from each other, and to have constructed a planetarium, or exhibition of their motions.

B.C. 135.—HIPPARCHUS (first of Rhodes and afterwards of Bithynia and Alexandria), is called "the great father of true astronomy." He first prosecuted the study systematically, and introduced trigonometry (see pp. 16—17);—By comparing his own observations with those of Aristarchus he corrected the computed length of the year, and brought it very near to the precision of modern times. He discovered the excentricity of the planets and the lunar inequalities; and in the laborious study of his own observations, and those of Eudoxus and others, he first recognized that slow apparent motion of the stars eastward, which, after being variously estimated by succeeding astronomers, led Newton to infer the fact of the *Precession of the Equinoxes*. (See illustration, p. 354, &c.)

It is from the projection of Hipparchus, that our maps and nautical charts are principally constructed.

⁂ *The science of Astronomy made little progress in the* *hands of the Greeks or Romans, during nearly* 300 *years; viz., from Hipparchus until—*

A. D. 120.—**PTOLEMY** (of Alexandria), who made observations of his own, constructed various tables, and preserved and transmitted the observations and principal discoveries of the ancients. His system (named after him the Ptolemaic), which is very similar to that adopted by Plato and Aristotle, placing the earth as the centre of the universe, was generally admitted for *fourteen centuries,* and is still held sacred by the Arabs, Persians, and Indians.

Ptolemy improved the trigonometry of Hipparchus, and is generally allowed to be entitled to admiration, for the persevering industry which aided his penetrating genius in making discoveries of great nicety, although upon false and very complicated hypotheses.

⁂ *During the long period of* 500 *years, there were various commentators on Hipparchus and Ptolemy; but no remarkable astronomers.*

A. D. 640.—The Alexandrian Library, (the general depository of all human knowledge,) burned by the Saracens; and the cultivators of science, assembled from every nation, dispersed in ignominy and distress.

A. D. 750.—**THE ARABIANS** became admirers and cultivators of the very science which their progenitors had nearly annihilated; and studied those works of the Greek authors which had escaped the conflagration at Alexandria. (This applies also to those Moors who had taken possession of Spain.)

A. D. 813.—**AL MAMON** (Caliph of Bagdat) himself an able astronomer, caused the "Almagest," or great work of Ptolemy, (saved from Alexandria,) to be translated into Arabic; observed the obliquity of the ecliptic, and measured a degree of the meridian.

A. D. 860.—**THEBIT** (a Jewish analyst, geometer, and astronomer) corrected the observed obliquity of the ecliptic, and determined the length of the year to be very nearly that established by modern observations.

A. D. 879.—**ALBATEGNI** (a Prince of Syria and Mesopotamia, "the Ptolemy of the Arabs,") corrected the observed apparent motions of the fixed stars;* discovered the shifting of the moon's apogee;—found the true length of the year within *two* minutes;—and formed new tables of the planets.

A. D. 1020.—ARSACHEL (a Moor of Spain) improved trigonometry by constructing tables of the *sines*, instead of the *chords*, of arcs (F, p. 17);—discovered certain inequalities in the apparent motion of the sun.

ALHAZEN (cotemporary) is said to have discovered the laws of *refraction*, (R, p. 185,) and to have pointed out the true cause of the morning and evening crepuscula.

NOTE.—*During a period of* 500 *years, (viz., from A. D.* 800, *until the beginning of the fourteenth century,) the western portion of Europe was immersed in darkness. The settlement of the Moors in Spain, it may be said, however, had introduced the sciences.*

A. D. 1230.—THE EMPEROR FREDERICK II. first began to encourage science by founding a university at *Vienna*, and caused the works of Ptolemy to be translated from Arabic into Latin.

ALPHONSO (King of Leon and Castile) cultivated astronomy himself, and encouraged a number of Jewish, Christian, and Mahometan astronomers of Spain in the pursuit of it. He is said to have ridiculed the complexity of the Ptolemaic theory.

ROGER BACON (an English monk) also, about this time, wrote tracts on the lunar aspects, the solar rays, and the places of the fixed stars.

A. D. 1400.—ULUGH BEIGH, (a Tartar Prince, son of the Sultan Shah Rohk,) himself an astronomer, formed a seminary for the learned at Samarcand;—constructed an observatory, and invited men of science to his capital;—left behind him a series of observations on the fixed stars.

A. D. 1500.—JOHN WERNER (a clergyman at Nuremburg) constructed a planetarium on the Ptolemaic hypothesis;—comparing his own observations on the fixed stars with those recorded by Ptolemy and others, he calculated the rate of their apparent motion in longitude; (*see Precession*)—he first proposed the method, now in use, of finding the longitude at sea by observing the distance of the moon's place from a star.

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* Hipparchus and Ptolemy had thought the apparent motion of the stars in longitude was one degree per 100 years; Albategni considered it to be one degree per 70 years. (Modern science has ascertianed it to be one degree in 72 years).

A. D. 1507.—For COPERNICUS (see p. 214).

A. D. 1550.—TYCHO BRAHE (of noble Danish family) was the inventor of a system intermediate between the Pythagorean or Copernican and the Ptolemaic,—assigning the centre of the universe as the fixed place of the earth, but allowing the sun to be the centre of the orbitual motions of Mercury, Venus, Mars, Jupiter, &c. Tycho was, notwithstanding, the author of many brilliant discoveries.

For KEPLER, GALILEO, &c., *see* "*Progress of Physical Astronomy*," pp. 213—215.

APPENDIX,

CONTAINING

MEMORANDA IN VERSE.

NUMBER I.

A PLANETARIUM.

Sir J. Herschel, who disapproves of "those very childish toys called orreries," gives the following, as an illustration calculated to convey a correct general impression of the relative magnitudes and distances of the parts of our system:—

"Choose any well levelled field or bowling-green. On it place a globe two feet in diameter; this will represent the sun: Mercury will be represented by a grain of mustard seed, on the circumference of a circle 164 feet in *diameter* for its orbit; Venus a pea, on a circle 284 feet in diameter; the Earth also a pea, on a circle of 430 feet; Mars a rather large pin's head, on a circle of 654 feet; Juno, Ceres, Vesta, and Pallas, grains of sand, in orbits of from 1000 to 1200 feet; Jupiter a moderate-sized orange, in a circle nearly half-a-mile across; Saturn a small orange, on a circle of four-fifths of a mile; and Uranus a full-sized cherry, or small plum, upon the circumference of a circle more than a mile and a half in diameter."

In the lines next following, the scale of distances and magnitudes just given from Sir J. Herschel is nearly preserved:—

1

Round a *two-feet-wide* SUN
Let a *Mustard-seed* run;—
☿ 'Tis the THIEF-GOD—at *twenty-eight yards!*
And at *twenty yards more*
Let *a Pea* range the floor,
♀ For the GODDESS OF TENDER REGARDS!

2

Shall there be, too, a *Pea*,
Fitting model of thee!
⊖ Mighty EARTH! with thy *millet-seed* MOON!
At but *six dozen yards*
Shall the high-minded "lords
Of creation" glitter in noon!

3

From great Earth, globule star!
Pass we then half as far
As she is removed from the Sun;—
♂ And the WAR-GOD'S grim face
A *wasp's head* might disgrace,
As his drear sullen circlet is run!

4

On! on! far to rove,—
♃ We'll at *cricket* with JOVE! *
Earth rolls *not one fifth* from the Sun.
Ah! desolate sight!
⚶ ⚵ Those *grains of dimm'd light*
⚳ ⚴ Which midway may have circled in one! †

5

But enough now of cricket,—
Away from the wicket
We'll pass *near three hundred yards more*,
And play *catch-ball* and *quoits*;
Nor forget the exploits
♄ Of SATURN and Latium of yore!

6

But we fain would not tire thee;—
Is it hard to desire thee
To *double* the journey thou'rt come?
Go, now, cool down thy heat
In yon shady retreat,
♅ And let URANUS treat with a *plum*!—

---

* A *cricket-ball* is here given as a representative of Sir J. Herschel's *orange*, and a *catch-ball* represents Saturn below, instead of a *smaller* orange.

† See L, on p. 270.

NUMBER II.

THE ORDER AND PLACES OF THE SYMBOLS ON THE ECLIPTIC.

⁂ *The first and third lines contain the ascending, and the second and fourth, the descending signs.*

The Ram ♈, and the Bull ♉, and the Twins ♊,
Crab ♋, Lion ♌, and Virgin ♍ above: —
Scales ♎, Scorpion ♏, Archer ♐,—bright signs!
Goat ♑, Waves ♒, Fishes ♓, southerly move.

NUMBER III.

The Ram and Bull, we'll keep in view,
Are No. *one* and No. *two;*
But it may oddly sound to thee
That Gemini should number *three;*
Or Cancer, on our north-east shore,
Should sideway crawl on number *four!*
Walk up! our Lion's quite alive!
His paws and tufted tail are *five*:—
When him you've view'd, in mem'ry fix
The Giantess * at number *six*.
How should those Balances be even?—
An equipoise of number *seven!*
Will it for evenness avail
To take *eight* knots from Scorpio's tail?
Blame not this hobbling Muse of mine,—
'Tis Sagittarius lames "*the Nine!*"
Consult a Goat for music then!
Whose eyes, ears, horns and feet are *ten!*
'Twill take an hour to reach yon haven,—
Then call Aquarius at *eleven;*
And, when we've thus attain'd our wish,
We'll dine at *twelve* on yonder Fish.

The lines of No. 3 are useful in finding the places of planets, &c., when their longitudes are given in signs and degrees.

Thus, if ♃ were in 8 signs 7°, i. e. 7° in the *ninth* sign, it will be easy to associate "the *Nine*" with the deeds of "*Sagittarius*," &c.

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* i. e. Virgo (a large constellation).

NUMBER IV.

THE DAYS ON WHICH THE SUN ENTERS THE DIFFERENT SIGNS.

On *March twenty-first,*
As the RAM quench'd his thirst
He frighten'd the neighbouring fishes:—
But he gambol'd the green
Until *April nineteen,*
When the BULL put an end to his wishes!

On *the twentieth of May,*
(A serene sunny day,)
The TWINS were for holy days wishing;
But were "kept in" 'till noon
Twenty-first of glad June,
When they ran, without leave, to CRAB-fishing.

Now LEO's roar nigh,
Twenty-second July,
Shakes the shore like the clarion's war-gust!
'Till the brute's rav'ning pace
Yields to VIRGO's soft grace,
On the calm *twenty-second of August.*

So mild Justice prevails
When fair truth holds the SCALES
On the *twenty-third day of September:*
Mark her face! need she fear
*Twenty-three** drawing near,
Or fell SCORPIO's venomous member?

Hark away! Tally ho!
With a horse and a BOW,
After *twenty-two days of November;*—
At the Solstice, afloat,
We'll let fly at the GOAT
On the *dark twenty-first of December:*—

---

* i. e. the *twenty-third* of October.

But see Sol's length'ning beams
On yon WATERMAN'S streams!
Of that *twentieth* old *Janus* * be wary;—
For, against his stern wish,
I caught two of his FISH
On the *nineteenth* of last *February!*

NUMBER V.

THE SIGN AND DEGREE BELONGING TO THE FIRST DAY OF EACH MONTH.

On New Year's day, (as hist'ry notes,)
A shepherd led *ten* frisking GOATS
To browse o'er yonder strand;
But February dawn'd,—he fled!
Twelve mountain WAVES the pasture spread,
And delug'd all the land;
And blust'ring *March,* his cheeks distorting,
Saw o'er green fields *ten* FISHES sporting!

When waves as vapour clothe the sky,
And *April* show'rs, and zephyrs sigh,
Eleven RAMS the pasture share!
'Till May, with aid of Flora's grace,
So fertile finds his dwelling-place
Ten BULLS can fatten there;
And *June* beholds sad truant deeds,
Ten TWINS wide roving o'er his meads!

On *July first* I search'd the shore
And found *eight* sid'ling CRABS,—no more—
For soon 'twas time to flee;—
August sent *eight* fierce LIONS down
From yonder heights that darkly frown
In leafy majesty!
September's ninth fair VIRGIN daughter
Repulsed the brutes, and sav'd the slaughter.

---

* i. e. the *twentieth* of *January.*—The ancient Janus was represented with two faces.

October low'rs, and sore bewails
The oddness of his *seven* SCALES;
And much he frets, and fears
November, brooding treach'rous things,
Who hides *eight* SCORPIONS 'neath her wings,
The Harpy of our years!
But we'll away and, glad, remember
Thou hast *nine* ARCHERS, brisk *December!*

*** The foregoing lines (No. 5) will be found of very ready service in ascertaining the sun's place for any proposed day;—for, since the sun's rate of apparent motion is about one degree per diem, *we shall always get an answer sufficiently correct, by merely adding the day of the month to the number given for the first day of that month.*

N. B. If the date should be so far advanced in the month, as that the addition of it to the number given produces more than 30,—the excess will shew so many degrees in the next sign.

Examples.

For the sun's place on the 15th July, add 15 to "*eight* sid'ling Crabs," and we get 23° in *Cancer.*

For 9th February, add 9 to "*twelve* mountain waves," and we get 21° in *Aquarius.*

For 26th October, add 26 to "*seven* Scales," and we get 33°, shewing the sun's place to be 3° in the next sign, or 3° in *Scorpio.*

NUMBER VI.

CONSTELLATIONS*

VISIBLE IN 50° NORTH LATITUDE,

Taken in their average declination, and in the order of their appearance from left to right, as viewed in north latitude.

> " The constellations seem to have been almost purposely named and delineated to cause as much confusion and inconvenience as possible. Innumerable snakes twine through long and contorted areas of the heavens, where no memory can follow them; bears, lions, and fishes, large and small, northern and southern, confuse all nomenclature, &c. A better system of constellations might have been *a material help as an artificial memory*."—*Herschel's Astronomy*, p. 163 *(note)*.

* These Rhymes on the Constellations have been found of considerable assistance, not only in seeking an acquaintance with the *pictures* of the celestial globe, but in tracing these imaginary forms in the sky.—For the Great Bear is known to every one; and, as may be seen, the beginning of each circling section, 1, 2, 3, 4, may be referred to URSA MAJOR.—Thus, the second begins with BOOTES (" *Arctophylax*," or the *Bear-keeper*)—the third begins with LEO (" under feet of the Bear")—the fourth, with the SEXTANT (" under the Great Lion's paw"), &c.

1.

'Twill be hard to describe
So motley a tribe :—
URSA MAJOR, CAMELO-PARDALIS,
Lofty " CASS " (*a*), and HER KING (*b*),
And DRACO, dread thing!
And yon LESS BEAR, who tied (*c*) by the tail is!

---

a That is, Cassiope (four syllables with the accent on the second) or Cassiopea, (accented on the penult) the wife of Cepheus.
b *Cepheus*, a king of Æthiopia.
c The pole-star is at the end of the tail of Ursa Minor, which therefore appears to revolve about it, as if thus " tied."

2.

Bright BOÖTES * still thinks
His DOGS chase the wild LYNX,
But AURIGA must guard his CAPELLA :—
Hast thou read classic lore
Of bold PERSEUS of yore?
Of the GORGON (*d*), and all that befel her?

Through the glass, O! how grand
Is that nebulous hand (*e*)!
And *Algol* how strange (*f*) in the other!
For the Daughter (*g*) in zeal
Let him brandish his steel;
But beware of the Throne of the Mother.

Hark! 'tis CYGNUS that sings (*h*)
As she flaps her wide wings,
And yon milky-white stream how she stems!
Snatch the LYRE, as 'tis meet,
From huge HERCULES' feet,
And tune high to CORONA's bright gems.

3.

Under feet of the BEAR
Is the LIONS' dread lair;
But the CRAB lies unhurt at their noses!
Much more wonderful still
Is yon neighbouring hill
Where each TWIN in soft safety reposes!

Have a care, my good boys,
Of yon horns,—or your joys
Will be sorrows! Haste, some one to seize him
Place TRIANGLES for check
Over TAURUS's neck,
And let MUSCA leave ARIES to tease him.

---

* Boötes is also named "*Arctophylax*," or the Bear-ward; but his occupation, judging from the engravings generally introduced on the globe, is that of hunting the lynx.

d The head in the left hand of Perseus is that of Medusa, the only one of the Gorgons subject to mortality.

e See Z, on page 275.

f See description of Variable Stars on page 280.

g Andromeda, the daughter of Cepheus and Cassiope, who was about to be sacrificed to the rage of a sea-monster when Perseus rescued her.

h The ancient poets fabled the singing of swans.

Fair ANDROMEDA's grief
Shall soon meet with relief,
As her case we've already considered:—
Shall wing'd PEGASUS' pace
Never quit that square space (*i*),
Nor his hoof be removed from the LIZARD?

It is well he's confined
To the rock close behind,
Such a multitude seems to way-lay him!
Could the FOX save his GOOSE
If he were to get loose,
Or DELPHINUS, or AQUILA, stay him?

SERPENTARIUS dreams
Of no danger it seems,
But his head is surrounded with evil!
From that THREE-HEADED DOG (*k*)
Or dread HERCULES' log,
Even flinching, he'll flinch at his peril!

Can BOÖTES forget
Bright ARCTURUS is set
As the brilliant to buckle his knee?
Let not VIRGO despair,
BERENICE's bright hair
Shall unhurt by his DOGS ever be.

4.

Snatch the SEXTANT (*l*) from under
The GREAT LION's paw yonder,
And steer clear over HYDRA's wide bay;—
Jump ashore, and astride
On MONOCEROS ride,
And let PROCYON (*m*) shift as he may.

---

i The large constellation of Pegasus may be marked by its three principal stars, which are nearly of equal brightness, and form the three corners of a square having, for its fourth corner, a star of equal magnitude in the head of Andromeda.

k In most of the representations of Hercules given on celestial globes, he holds in one hand what may be supposed to represent the trophy of his twelfth labour, Pluto's three-headed dog Cerberus; and in the other his club.

l The Sextant is a constellation very inconsistently imagined by Hervelius, a German astronomer, in the 17th century.

m *Procyon* is derived from two Greek words, signifying that the star precedes the dog. The star had also the synonymous Latin appellation "antecanis" (antecanem), because it rises before Canis Major, or *Canicula*, the "Dog Star."—Canis Minor appears, on our globes, to be riding on the back of Monoceros.

Hark!—did'st hear that loud cheer?—
Let ORION appear!
Check the rein, nor approach thee too near him;—
Mighty Nimrod (*n*) of old,
Not more bright nor more bold,
Made the whole of the nations to fear him.

Bring the glass, and survey
That most brilliant array!
Look at *Rigel* (*o*) his spur! and his shoulders!
Bellatrix! Betelgeux! (*o*)
O how dim are the Duke's!
And his scabbard (*p*) what worlds for beholders!

Why, that SCEPTRE (*q*) he'll kick
Like the commonest stick!
See it into ERIDANUS rolling!
(O were CETUS' wide mouth
Very little more south!—
Then we loyals must up and go polling!)

Most odd-FISHES are they!
Although coupled they stray!
One nibbles ANDROMEDA's vest;
Whilst its fellow holds course
Under wing of the HORSE,
And seems to like southern things best,

For he's "crossing the line":—
But I cannot divine,
In the stream from AQUARIUS' urn
'Though small fishes may float,
How that monster SEA-GOAT
Can find depth or find width to return.

---

[n] Orion is celebrated as a hunting companion of Diana, of uncommon strength and stature. Nimrod, the great-grandson of Noah (mentioned Gen. x.), began his conquests as "a mighty hunter."

[o] Rigel, in Orion's heel, is a double star,—the individual stars being of very unequal magnitudes:—Betelgeux is a larger star than Bellatrix, and in remarkable contrast with Rigel for the redness of its light.

[p] The middle part of the scabbard of Orion's sword, which to the unassisted eye appears as a small and very dull star (θ), is one of the most wonderful objects to which the telescope can be directed. It is a great nebula of remarkable form, in which are interspersed between fifty and sixty small stars.

[q] The Sceptre, at the foot of Orion, is not pictured on some globes.

Young ANTINÖUS scorns
CAPRICORNUS'S horns,
But his Carrier's (*r*) talons must tear him;
To be sure he'll be heal'd
If, in passing the SHIELD,
The EAGLE to westward should bear him:—

OPHIUCUS' skill'd hands
Seem to wait for demands
While the Doctor that SERPENT is plying;
Esculapian (*s*) pride!
Like his med'cine, aside
His SCALES are in idleness lying.

Pass the Doctor, for look!
We have work for the Cook!—
See a *Fowl*, and some *Corn* (*t*), and the CRATER!
How is appetite now;—
Yonder Fowl is a CROW?—
Let our Cook try her skill somewhat later!

5.

Near MONOCEROS' feet
And ORION'S, there meet
CANIS MAJOR, the HARE, and the DOVE:
Near the tail of the Whale is
Bright PISCIS AUSTRALIS,
Who swallows the *stream* (*u*) from above.

Turning back from the GOAT,
SAGITTARIUS shot
At the SCORPION'S mischievous (*v*) station!
It were well if each aim
Of all sportsmen could claim,
So fairly, its justification.

---

r Aquila, the Eagle, the bird of Jove. Some have imagined that this represents Jupiter, who is fabled to have assumed the form of an eagle to carry off Ganymede.

s Ophiucus (from two Greek words signifying *serpent-holding*) represents the ancient Æsculapius, the god of medicine, whose symbol was a serpent.

t Spica, the ear of corn in the hand of Virgo.

u The stream from the urn of Aquarius.

v The Scorpion appears as if about to attack the foot of Ophiucus, or Serpentarius.

A NOTICE OF SOME PHENOMENA OF THE HEAVENS,

Presented during the first of September, in lat. 50° N. ± whilst journeying in the plane of the meridian.

The pupil must accommodate the lameness of the poet, by stretching his thoughts over a champaign of twelve miles' extent (somewhere in latitude 50°)—having some hills in the extreme south, with the sea lying toward the west of them.

A stile is to be supposed at no great distance southward of the Rhymer's residence; leading, first, to a village road;—on the left (or east) of which is a lake of considerable extent, bordered on its farther side by a wood;—and the road from this stile throughout the said champaign is generally uninterrupted.

Set now thy face towards where the Sun [*]
Appears;—just half his day-task done!
We'll pace, due southward as we can,
The "*Plane of the Meridian*" (*a*):—
But mark his course,—Sol's tow'ring height
Droops from this instant towards our right;—[†]
His *Azimuth* (*b*), "east from south" before,
Now westward reckons more and more.

Keep on!—we'll give thee twelve good miles
To the south green 'midst yonder hills,
And thou shalt rest those willing feet
The instant that his disk shall set.

But stop!—pray gather in thy breath,
We'll not astronomize to death!—

---

[*] The apparent diameter of the sun, which may be found by the time it takes in crossing the meridian-wire of a transit instrument, is, on the 31st of December, 32′ 35″; and on the 1st of July, 31′ 31″. This difference arises from our own change of distance, whilst revolving about him in an ellipse.

[a] See def. 18; and G and its note, on p. 9.

[†] It will be borne in mind, that this is when the observer is north of the sun; as his westward apparent motion will be towards the "*left*" of any one looking at the sun from a station south of him.

[b] See def. 45, and its note.

Point that warm finger over-head,
Then through him to yon ocean-bed:—
Now, reckon the degrees between
That finger and thy resting green,
(In yonder clear horizon seen:—)
It is this moment's Azimuth,—
Sol's bearing from the distanced south!
Next, mark the hour and minute hands
Where yonder ivied turret stands;—
'Tis *five* o'clock,—and thus (*c*) is given
This morning's Azimuth at *seven*.

Here see thee safe! and down he goes!
Take (*d*) *Amplitude* ere we repose:—
"Twelve from the west toward the north:"—
Now rest! and—"Waiter! lay the cloth!"

* * *

O wise the laws of adaptation
In our, and every other, station!
By air's refraction and reflection (*e*)
Antipodes e'en have connexion!
Our's saw Sol rising ere he set;—
(Thus cannibals and courtiers met,
At least in gazing):—but anon
We'll dwell this subject more upon.

Sol's disk has gone,— not all his beams!
See how yon crimson'd lattice gleams!
Whilst we refresh he'll still supply
Our twilight, nor his aid deny
Though yet he glows in Zealand's sky.

[Often, of earthly good bereft,
Man views his right hand and his left,
And says his "comforters" are gone,
And all is dimm'd on which they shone!

---

[c] The sun's azimuth from the south or north toward east in the forenoon, is the same with that from the south or north towards west in the afternoon.

[d] See def. 46, and its note.

[e] See note 4 of M, on page 183; and R and its note, on p. 185. A party of Dutchmen, who wintered (1596) in Nova Zembla, (lat. 76) saw the sun of 1597, six days before his time. The elevating effect of the refraction of our atmosphere on an object at 45°, or half-way between the horizon and the zenith, is about 1′ only; but at the horizon it is, at an average, as much as 33′, or more than the whole apparent diameter of the sun or moon.

O, did he straightway raise his view
Towards Him who takes, but gave them too!
E'en a soft radiance would he find
Beaming from mercies left behind,
Till stars break forth, or op'ning day
Shall cheer and guide his future way.]

Now to return:—Can'st thou help find
The homeward track we left behind?—
'Tis dark! nor moon nor star is seen
To guide us o'er this mazy green!—
The mariner's unfailing friend (*f*)
Must shew which way our steps must tend:
But mark! this quiv'ring variation (*g*)
Is westward of our *northern* station;
It points near *twenty-five* degrees
To its own pole in icy seas;—
We'll keep its tendency in sight,
And *bear just so much to the right.*

See here the stile! our northward track
Lies beaten all the journey back!
(When some, who, as the Scriptures say,
Have cried, "A lion's in the way!" *
Begin with honest, earnest, eyes,
To seek the aid their lot supplies,
Quickly the raging phantom flies—
They gain a friendly stile, and bless
The road of ease and happiness!)

I'm glad to see thee "staff to shoulder,"
Mine aids two legs grown somewhat older:—

---

f See MAGNETISM, on pp. 200, &c. It is uncertain which nation first made use of Magnetic Polarity to determine positions on the surface of the globe:—"It is said that a rude form of the compass was invented in Upper Asia, and conveyed thence by the Tartars to China, where the Jesuit missionaries found traces of this instrument's having been employed as a guide to land travellers in very remote antiquity. From that the compass spread over the east, and was imported into Europe by the Crusaders."—*Mrs. Somerville.*

g See Y, on p. 204, and C, p. 206. Columbus is said to have first noticed the variation of the compass as he crossed the Atlantic.

* Prov. xxii. 13.

Now learn! were thine, thus plac'd, to grow
To height of fir 'midst Alpine snow,
And did that knot its fibre shoot,
'Till earth's dark centre felt it root;
Those feet, that shoulder, fibre, stem,
Whilst north as now thou beared'st them,
How far soe'er thy steps might go,
Would "*Plane of the Meridian*" (*h*) show.

But see the mists dissolve! and, through
Yon curtain'd gauze, the spangling blue
Bears Luna's dwindled face to view!
She, "faithful witness!" to our eyes
Reflects the light of hidden skies;
Yet, busied thus earth's sons to bless,
Still more intent (*i*) her course to press!

(Daily like her's be thy course run;—
Like her keep nearing to thy Sun!
And more of *inward* lustre find,
As earthling eyes thou leav'st behind;
Till, cloth'd, like seraph, in His light,
Thou disappear from mortal sight!)

Though north of east, her cusps display
Their silver with but feeble ray;
And late her rise, and short her stay;
But whene'er whit'ning fields shall bend
Burthen'd with blessings, she'll attend,
Prompt (*k*) with her fullest lamp, to light
Our needy North throughout the night;
And, crossing the Prime Vertical
As loath to quit the scene, she'll fall
Far past the west at morn (*l*), to make
Her absence short for harvest's sake.

Do'st wish to know
What gave me the due east just now?

---

h See G, and its note, on page 9.
i See illustration of the moon's real path, on page 309.
k See "HARVEST MOON," page 318.
l M, on page 319.

Yon rising triplet cast thine eye on,—
The girdle gems (*m*) of bright *Orion!*
One shines upon the *Equinoctial*,
Ninety degrees from yonder *Pole*;
And ev'ry star in that line placed
Rises and sets due east and west:—
Great Sol himself will there appear
Twice as he measures out our year!
And equal, then, his kindling sway
In *northern*, or in *southern*, day,
O'er *Sandwich land*, or *Melville Bay*.

See yonder *Bear!* his tail is curved!
(Earth's bears are *tailless* (*n*) be't observed)
Just now his head is east of north,
And he seems growling gruff, in wrath
At rising *Twins*, and fair *Capella*,
As old *Auriga* goes to sell her!

Some take that tail for wagon-horses,—
His brilliant back the *Wain* (*o*) of course is;
Now, tie those hinder wheels together
And stretch the cord;—'twill serve to tether
Yon Little Growler by the tail (*p*)!
Thus seek the *Pole* and never fail.

(But yonder *Polar Star* is placed
Or high, or low, or west, or east,
Near two degrees (*p*) by our revolving:—
I'll leave this problem to thy solving.)

---

m The most northern of these three remarkable stars, is about half a degree south of the equinoctial. There is no other remarkable star shining on it. See also Example 9, on page 129.

n Professor De Morgan quotes the following from an old work on the stars:—

"*Scholar.*—I marvell why, seeing she (Ursa Major) hath the forme of a beare, her taile should be so long.

"*Master.*—I imagine that Jupiter, fearing to come too nigh unto her teeth, layde holde on her tayle, and thereby drewe her up into the heaven; so that shee of herselfe being very weightie, and the distance from the earth to the heavens very great, there was great likelihood that her taile must stretch:—Other reason I know none."

o "When men indicate the stars by figures borrowed from obvious resemblances, they are (often) led to combinations quite different from the received constellations. Thus the common people of our own country find a wain or wagon, or a plough, in a portion of the great bear."—*Whewell.* Homer also calls the Great Bear, a wain. Od. 1.

p The star of the second magnitude, called the Pole-star, and which is at the tip of the tail of Ursa Minor, is not at the polar point, but 1¾° removed from it; and hence appears to revolve around it in a circle of 3½° diameter.

What's here? our other crossing stile!
Now let us sit and rest awhile:—

[Impediments thou'lt oft-times meet
As life employs thy busy feet;
But if, as now, thou stop to muse,
(As they are given thee to use)
And turn thine eyes, and view the road
Which, oft, too thoughtless steps have trod,
And, resting grateful thus, survey
The glowing mercies of the way!
Full many a hind'rance, in the end,
Will prove,—like this good stile,—a friend.]

* * *

Now try if Luna's loftier face
Enable us the time to trace;—
See *Aries'* head is *culminating* (*q*);
In "periwig of wool" debating
The straightness of the road we've come:—
We're near arrived,—he's *half-way* home:—
(Do'st think he's envious? O, no!
Envy is dark, and dwells below!
Is't pride so lifts his head on high?—
There is no pride above *our* sky!)

'Tis now past *three;* he rose at *seven;*
He'll set this morning at *eleven:*
Thus, (it is worthy of remark,)
Across our southern track, each spark
Measures its *half diurnal arc* (*r*).

* * *

See *Cygnus* dives, as if to rest!
In az'muth (*s*) 'thirty north towards west;'
Whilst *Aquila*, Jove's errand slighted (*t*),
Dropping *Antinöus* west, alighted,
As *Canis Major's* brilliant nose (*u*),
Full scent on *Lepus* just arose!

---

[q] See G, page 9.

[r] See '*Remark*' to Problem VII., page 80.

[s] Note to F, page 8. In lat. 50° N, γ, the middle star of Cygnus, only touches the north point of the horizon.

[t] See '*Antinöus*' (*Rhymes on the Constellations*).

[u] *Sirius*, the brightest of all stars, is at the nose of *Canis Major*.

See *Rigel, Procyon, Sirius!* rays
That record bear of ancient days;
When she who gave fair Science birth,
(Now "basest" of the realms of earth!) (*v*)
Not choosing to retain the light,*
Was "given o'er" to groping night!
And "changed the Truth" of the Most High,
Into a grov'ling, dark'ning "lie!"
Bringing earth's hallowed offerings
To lowing, mewing, creeping, things! (*w*)
And deeming yon mere brilliant beam (*x*)
Pow'rful to pest or heal her stream!

And what where Science stateliest grew?
('Midst Grecia's shades her steps pursue,)
Could her trim lamp the sun renew!
View yonder forms!—each cries aloud
"The world by wisdom knew not God!" *

But what view'st *thou* in yonder star? (*z*)
Where drops its vertex ray?—afar—
O'er swarthiest Madagascar!
O! I have seen who late had crossed (*a*)
Ocean's wide wave from that dark coast,
Who brav'd the torture-screw and spear,
Not counting life as conscience dear,
Whilst heathen tyrant raged near!
And still there stand, (*b*) on that stain'd shore,
Compeers of suff'ring saints of yore!

---

v The extreme degradation of Ægypt was foretold. (*Ezekiel* xxix. v. 15).

* Rom. I. v. 21—28.

w The ox, ape, crocodile, cat, beetle, &c., were objects of ancient Ægyptian idolatry.

x The Ægyptians paid divine honours to Sirius, under the name of *Isis-Sothis*. (*See note on page* 369.)

† 1 Cor. I. v. 21.

z About 4 o'clock A.M., 2d of September. Sirius vertical near Cape East Madagascar.

a The Malagasy refugees are fine modern examples of the converting and sustaining power of the gospel. Of these six Christians, two are females, and one of them, Rafaravavy, a woman of rank, who, in the days of her ignorance, was a zealous promoter of the idolatrous superstitions of her country. They arrived in this country in June, 1839, from the Mauritius, having, after several months of imminent peril, escaped thither from the persecuting fury of the queen of Madagascar.

b On the 9th of July, 1840, (since the above was written,) nine of the numerous native Christians of Madagascar suffered martyrdom. On their apprehension they thus addressed the agents of the government:—"*We are not banditti or murderers, we are praying people; and if this make us guilty in the kingdom of the queen, then, whatever the queen does, we submit to suffer.*"

Lifting faith's waiting eyes, to trust
His arm who vindicates the just!
And thus, in pointing yon fair gem
Whilst thus we sit, thou point'st to them!

[But be aware!—to all not nigh
We point amiss (*c*) not pointing high:—
So when, with critic gaze, we scan
Each foreign view of Christian man,
We judge amiss; Earth *warps* our view;
(As all truth one horizon knew!)
But when, with loftier aim, the eye
Seeks guidance beaming from the sky,
And faith regards, with nobler sight,
The *purely* true in *perfect* light;
We feel that all are joined above,
We own our brethren, and we love!]

Trace now the Ecliptic, (*d*) we have seen
Aries on the meridian:—
The *Bull* and *Twins* stretch south and east;—
The *Fish* and *Water*, south of west;—
The *Crab*,—is on yon eastern shore;
The *Goat*,—will soon be seen no more. (*f*)
Near yon Ecliptic line there move
Mercury, Venus, Earth, Mars, Jove,
And *Saturn* with his double ring,
And *Herschel's* star, (mysterious thing!) (*g*)
Eight degrees, north and south, include
Each ever varying latitude (*h*);
Whilst *Luna* on her monthly road
Crosses it twice to form her *node* (*i*).

How tenderly the moon's white flood
She pours, to hush yon margin wood (*k*)!
And each leaf sleeps! Nature's pure child
Which, at late eve, was dancing wild

---

c See 'Remarks' and their note, preceding Problem IX. on pp. 84—85.
d See def. 61.
f That is, is nearly setting.
g See H on page 5, and 'Uranus' on p. 263.
h See 'latitude' of a heavenly body, on page 153.
i See pp. 304, &c.
k See note at the commencement of this piece.

To watch yon lake's red wrinkling face
Mock all around with broad grimace.
Now see demure that mimic lie,
To picture true yon vaulted sky;—
Approach his faithful brilliant sketch,
And her swift wing let Fancy stretch
From Zealand's zenith (*l*) aid to fetch,
And what find'st thou?—*the perfect Sphere!*
Thyself,—alone! *the Centre,—here!* (*m*)
And Earth?—is not! or gleams afar,
Near yonder speck, the duller star!
Where pride? where slavery, and war?
O! where she rolls 'midst sister spheres
Is there one else in sin!—in tears!

Or, can it be! amongst yon vast,
One else rebellious, which the blast
Of Justice have not yet o'er-pass'd!
Yet, hover angels there to bring
"Glad tidings?"—or do seraphs sing
Of pard'ning love for sinners there?
As when, of old, Earth's tainted air
Rang extasy, * that Jesu's grace
Made her, marr'd speck, His dwelling place!

But where is Earth if yonder zone (*n*)
Of milky film contain the Sun?
If he, transplendent "star of day!"
In yon abyss can lose each ray?
Or all day's glories must unite
To form one speck of faintest light!
(Mere misty speck great Herschel deems
From many a firmament he seems!)
O what is Earth! what Earth's chief throne,
When laurell'd, crimson'd, toil has won
The shifting heap to pant upon!
Yet lowly thou, and meaner I,
Link'd to their Lord's infinity,

---

l Our antipodes, (somewhat south of New Zealand) having, at any time, above their horizon, the hemisphere of stars hidden from us.

m The *lower* hemisphere of stars being imagined to be that which appears by reflection in the lake, the observer may fancy himself to be at the centre of the great Celestial Globe of the sky.

* Luke ii. 13.

n The Galaxy, or milky way, (def. 107, and D and F, p. 276.) We could have wished that the moon had been absent, and that the time (4 o'clock) had been less advanced, in order to have had a better view of the galaxy.

As much are objects of His care
As all yon shining myriads are!
As vigilant His Eye of thine
As 'erst of Adam's young design!
Full o'er my path has mercy shone
As I had been His only one!
Who tends, as though its need were all,
The raven's cry, the sparrow's fall![*]

Now let us home:—what! take a run?
Leap'd over after all! well done!
The faint grows fresh as home he sees;—
There is a voice 'midst yon far trees,
A still small voice,—of sov'reign pow'r
In any clime, at ev'ry hour.
All stop to list to Philomel,
All love to hear the lark's full swell;
But they are melodies of *Spring;*—
Home's *Year* is tune,—her sparrows sing!

But what comes yonder, north of east?
A Herald! (*q*) to proclaim a guest
Who travels yet fifteen degrees
In view of our Antipodes!
He'll come; his rising place is known
Well as he "knows his going down."[†]

[Happy the man, by day, by night,
Safe guided by celestial light!
Thrice happy who, life's journey run,
Can feel life's 'journey-work'[‡] is done!
Who, through the chequered, careful, road,
Trusted a pard'ning, strength'ning, God;
And now, on earth, 'ere close his eyes,
Can trace the *twilight* of the skies!
Glad earnest of Heav'n's fullest ray
Of joy "laid up" against THAT DAY![§]]

---

[*] See quotation from *Whewell's Bridgewater Treatise*, G, on page 5.
q Twilight, the sun being within the distance mentioned, of the horizon.
[†] Ps. civ. 19. [‡] Job xiv. 6. [§] 2 Tim. iv. 8.

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(FOR INDEX TO PROBLEMS, SEE THE INTRODUCTION.)

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